NORMAN WELLS
RESEARCH AND MONITORING PROGRAM

Fifth Annual Summary Report

PREPARED BY:

BOREAL ECOLOGY

Boreal Ecology Services Ltd., Box 277, Yellowknife, N.W.T. X1A 2N2 Tel. (403) 873-5847

NORMAN WELLS RESEARCH and MONITORING PROGRAM

Fifth Annual Summary Report

CP(EP)WNR88/89-2C

Prepared for:

Environmental Protection
Conservation and Protection
Western and Northern Region
Department of the Environment
Yellowknife, N.W.T.

By:
Boreal Ecology Services Ltd.
Yellowknife, N.W.T.

April 1988

89-06109/

DISCLAIMER

This summary report was prepared by Boreal Ecology Services Ltd. of Yellowknife for Environmental Protection, Department of the Environment. The summaries are based on reports provided by the contributing agencies and the first, second, third and fourth annual reports of the Norman Wells Research and Monitoring Program. Observations and results reported here are interim findings and should not be regarded as final conclusions unless otherwise noted.

TABLE OF CONTENTS

Introduction 1

Program Coordination 4

1. Interprovincial Pipe Line (NW) Ltd. Monitoring Program 6

2. Environmental Baseline Studies 43

3. Island Monitoring and Mackenzie River Breakup 47

4. Air Quality Monitoring at Norman Wells 50

5. Permafrost and Terrain Research and Monitoring 70

   A. Thermal Regime and Terrain Stability 73

   B. Terrain Performance 96

   C. Evaluation of Wood Chip Insulation on Thaw Sensitive Slopes..... 109

   D. Soil Temperature Study 113

6. Studies of Environmental Effects of Disturbances in the Subarctic .. 121

7. Mackenzie River Contaminants Pathways 143

8. Mackenzie River Baseline Monitoring of Petroleum Hydrocarbons 156

9. Fish Quality and Physiological Condition 161

10. Aquatic Monitoring Study 169

11. Snow Goose Habitat Use 183

12. Raptor Monitoring Program 194

13. Wildlife Disturbance Monitoring 213

14. Renewable Resource Harvest Monitoring 217

INTRODUCTION

The Environmental Assessment (EA) Panel examining the Norman Wells Oilfield Expansion and Pipeline Project reported its findings to the Minister of the Environment in January 1981. Numerous recommendations were made regarding research and monitoring of the effects of oilfield and pipeline construction and operations. In August of 1981, the oilfield expansion and pipeline projects were granted approval by the Federal Cabinet. Approvals were contingent upon the submission of further information by the proponents, and were subject to a two-year delay to enable preparations by government, native organizations, and the public.

In August of 1982, the Deputy Minister of the Government of the Northwest Territories Department of Renewable Resources, Mr. James Bourque, proposed the development and implementation of an intergovernmental research and monitoring program for the oilfield expansion and pipeline projects. The purpose of this program was to test the validity of impact predictions identified during the environmental assessment and review process, and to test the effectiveness of mitigative measures identified during the regulatory process. Mr. Bourque further proposed four objectives for the program:

1. to determine and quantify environmental impacts and to examine recovery processes;
2. to compare actual and predicted impacts;
3. to evaluate the long-term effectiveness of mitigative measures; and,
4. to prepare environmental recommendations applicable to future northern pipeline and oilfield developments.

In September of 1982, a Working Group was established to develop and implement a research and monitoring program. The Working Group included representatives from:

The Department of Renewable Resources (GNWT)
The Department of the Environment (DOE)
The Department of Indian Affairs and Northern Development (DIAND)
The Department of Fisheries and Oceans (DFO)
The Department of Energy, Mines and Resources (EMR).

Over time, the Working Group has expanded to include:

Esso Resources Canada Limited
Interprovincial Pipe Line (NW) Limited
Dene Nation
Federal Pipeline Coordinator's Office
The Department of Agriculture (DOA)
The University of Alberta (U of A)
The National Research Council (NRC)

The initial task of the Working Group was to identify all environmental issues and concerns related to northern pipelines and oilfield developments. To this end, the reports of the Berger Commission and of the Norman Wells and Alaska Highway Gas Pipeline Environmental Assessment panels were thoroughly reviewed. The transcripts of the N.W.T. Water Board public hearings and reports resulting from the National Energy Board hearings were also reviewed. In order to make use of the extensive knowledge and experience gained in Alaska from the construction of the Trans-Alaska Pipeline System, a member of the Working Group visited Alaska in January of 1983 and consulted extensively with Federal and State officials who had been directly involved with environmental

regulation and monitoring. In return, two U.S. officials travelled to Yellowknife in March of 1983 and conducted a northern pipelines workshop for interested representatives of government, industry, native organizations, and the public.

Once the available information had been collected and assessed, the members of the Working Group established a set of priority environmental issues. For each priority issue, a research and monitoring project was developed under the sponsorship of one or more of the participating organizations. Over time, the list of priorities for research and monitoring has grown and now includes:

1. revegetation and restoration (including remote sensing)
2. artificial island integrity during Mackenzie River breakup
3. oilfield emissions and air quality
4. terrain performance along the pipeline
5. effects and effectiveness of wood chip insulation
6. thermal regime and ground stability along the pipeline
7. soil temperatures
8. forest ecosystem disturbances
9. contaminants pathways in the Mackenzie River
10. fish quality and physiological condition downstream of the Norman Wells refinery
11. aquatic impacts from the construction of pipeline stream crossings
12. snow geese and their habitat use
13. disturbances to raptors
14. disturbances to terrestrial wildlife
15. renewable resource harvesting

Preliminary field reconnaissance for most of the projects was carried out during the summer of 1983, and the majority of research and monitoring was well underway by the time pipeline construction began

in January 1984.

Now, in March of 1988, seven years following the Environmental Assessment and Review Panel report, the construction period is over and the oilfield and pipeline facilities have been operating for three years.

PROGRAM COORDINATION

The Working Group of the Norman Wells Research and Monitoring Program has met formally at a northern location in the fall of each year since 1983. At these meetings, the members of the Working Group have discussed results of individual projects, coordination between studies, requirements for further research and monitoring, and the preparation of environmental recommendations for future northern pipelines and oilfield developments.

The Working Group has strongly supported the concept of community-based environmental monitoring and has welcomed the participation of the public, both at its regular meetings and in its field projects.

Questions on the scope of the Norman Wells Research and Monitoring Program should be addressed to the Working Group Chairman:

Dr. Brian Wilson
Environmental Protection
Department of the Environment
P.O. Box 370
Yellowknife, N.W.T. X1A 2N3
(403) 873-3456

The following sections summarize the cumulative results of the research and monitoring projects conducted to date. This is the fifth annual report of the working group. Although some research and monitoring studies will continue for the next several years, the greater part of the Research and Monitoring Program has now been completed. It is therefore anticipated that the Fifth Annual Summary Report will be the last.

This summary is not intended to be a definitive or exhaustive description of each study and its results, but rather a collection of relevant information for the interested public. Persons wishing more specific information are referred to the researchers and to the specific reports listed in the individual project summaries.

Reports Available

Environmental Protection Service. 1984. The Norman Wells Research and Monitoring Program, Status Report. June 27, 1984. 15pp.

Boreal Ecology Services Ltd. 1985. Norman Wells Research and Monitoring Program, Second Annual Summary Report. April, 1985. prepared for Environmental Protection, Environment Canada, by Boreal Ecology Services Ltd. 62pp.

Boreal Ecology Services Ltd. 1986. Norman Wells Research and Monitoring Program, Third Annual Summary Report. March, 1986. prepared for Environmental Protection, Environment Canada, by Boreal Ecology Services Ltd. 125pp.

Boreal Ecology Services Ltd. 1987. Norman Wells Research and Monitoring Program, Fourth Annual Summary Report. March, 1987. prepared for Environmental Protection, Environment Canada, by Boreal Ecology Services Ltd. 184pp.

1. INTERPROVINCIAL PIPE LINE (NW) LTD. MONITORING PROGRAM

Agencies Participating

Interprovincial Pipe Line (NW) Ltd.
in cooperation with the Government of the Northwest Territories and the Department of Indian Affairs and Northern Development, with assistance from the Department of Energy, Mines and Resources, Agriculture Canada, and the National Research Council.

Start-up Date

1980 Baseline studies
1983 Construction monitoring
1984 Post-Construction monitoring

Objectives of Monitoring

1. to evaluate the environmental impact of pipeline construction and operation;

2. to identify the need for remedial measures and/or a change in design or procedures;

3. to assess the effectiveness of environmental protection measures; and

4. to establish reasonable environmental guidelines for future pipeline developments in the north.

Results to Date

Baseline Monitoring Studies 1980 to 1982.

Raptor Monitoring

Interprovincial Pipe Line (NW) conducted raptor surveys along the Norman Wells pipeline route in 1980 and 1981 to establish baseline conditions and raptor protection zones. Thirteen nesting areas were identified and three of 44 nests were occupied in 1981.

Wildlife Monitoring

Interprovincial conducted wildlife surveys of borrow pits and facility sites in the summer of 1982 and moose surveys along the Mackenzie River and Norman Wells Pipeline route in the winter of 1982. Low densities of animals were observed and the only significant concentrations occurred on alluvial islands of the Mackenzie River.

Aquatic Monitoring

Intensive surveys were conducted on the Great Bear River and Mackenzie River to characterize fish populations and streambeds in the vicinity of the pipeline crossings. Similar studies were undertaken for all Interprovincial facility sites.

Late winter surveys were conducted of 104 watercourses to assess the potential for fish overwintering in the vicinity of the pipeline crossings. Depth of water, flow rates, and dissolved oxygen concentrations were the major criteria in assessing overwintering potential. Results showed that 16 streams had overwintering potential near pipeline crossings.

Waterfowl

Surveys were conducted in the spring of 1981 and 1982 to determine open water conditions and waterfowl distribution before and during break-up. Data obtained in this investigation substantiate the results of earlier studies which found the Camsell Bend and Norman Wells regions of the Mackenzie River to be optimum areas during spring migration. The Camsell Bend area was used most intensively especially during early migration.

Other Studies

Interprovincial Pipe Line (NW) also undertook more than 75 other studies related to terrain typing and performance, erosion control, and reclamation.

Construction Monitoring 1983 to 1985.

Aquatic Monitoring

Interprovincial undertook several water quality monitoring programs in relation to pipeline construction activities in 1984 and 1985. Intensive water quality monitoring programs were undertaken at the Mackenzie River, Great Bear River, and Bosworth Creek which are all used as municipal water sources. Studies to determine fisheries habitat potential in the vicinity of pipeline crossings and to ascertain any significant changes to water quality resulting from construction activities were conducted on 34 other watercourses.

The results of the water quality monitoring programs indicated that pipeline construction activities did not produce significant environmental impacts. Clear water conditions prevailed throughout blasting, excavation, and backfilling on those watercourses used as

municipal water sources. Several other potability parameters sampled on these watercourses also demonstrated that the water remained a suitable source for domestic consumption throughout the construction period. Up to 21 parameters were analyzed, including turbidity and total suspended sediments.

Monitoring programs established to evaluate the impact of construction on fisheries habitat determined that only 18 of the 34 watercourses sampled had water quality parameters conducive to overwintering fisheries in the vicinity of the pipeline crossings. A continuation of free water flow and high concentrations of dissolved oxygen immediately downstream of these crossings indicated that construction did not impair these habitat criteria.

Wildlife Monitoring

Wildlife monitoring during construction involved three separate programs. Representatives of various Hunters and Trappers Associations were contracted by IPL to conduct wildlife track counts along the right-of-way during construction in 1984 and 1985. The second monitoring program involved track densities and browse use measurements along rectangular sampling transects with a 4 km perimeter. Two pairs of transects were established in each of six sampling areas and data were collected in January and March, 1985. The third program required IPL, construction, and regulatory personnel to record sightings of wildlife as encountered.

Utilization of available browse was found to be very low with only four percent of sampled shrubs showing signs of browsing. The majority of browsing by moose (74 percent) was observed at distances greater than 750 m from the right-of-way. However, some moose browsing was observed as close as 150 m from the right-of-way. The distribution of browsing by hare suggested no avoidance of habitats adjacent to pipeline-related clearings.

From the small number of tracks seen during the monitoring studies, it was inferred that the population of animals in the study regions was exceptionally low. Furbearer track data demonstrated no consistent, positive or negative responses to habitats adjacent to pipeline clearings, although the actual cleared areas were usually avoided by the animals. Track densities were too low for other wildlife species to permit trends in abundance to be assessed.

While some avoidance by moose of habitat adjacent to the right-of-way was suggested by these data, the very low utilization of browse, even in areas well removed from the pipeline, indicated that a reduction of wildlife carrying capacity was unlikely.

Throughout the period of mainline construction, numerous wildlife were observed on or immediately adjacent to the right-of way. The track count data collected by representatives of Hunters and Trappers Associations also provided evidence that all of the major wildlife species, including moose, at least periodically utilized the right-of-way. It appeared that any displacement of wildlife away from the right-of-way was minor and of short duration.

Post-Construction Monitoring - 1984 to 1987

Terrain Monitoring

Beginning in April 1984, routine surveillance patrols were conducted on a weekly basis and in certain areas more frequently. Included among these patrols were monthly investigations and readings at 69 instrumented sites. Furthermore, in 1984, 1985, 1986, and 1987 there were a series of special monitoring trips to investigate slopes.

Overall, terrain performance has been satisfactory. Areas which have experienced active erosion represent a minor portion of the total

right-of-way. The most extensive change in terrain condition continues to be subsidence of the ditch line below the original ground surface, although the rate of progression of this phenomenon has diminished significantly. Placement of borrow material to backfill subsided ditch was undertaken in summer and winter 1986 and 1987. A minor amount of backfilling of subsided ditch is planned for 1988.

No major slope instability problems have occurred although minor slumping was observed at a few locations in 1985 and 1986. Restoration works undertaken at certain slopes in the winters of 1985, 1986, and 1987 appear to have been successful. Water levels, piezometric pressures, and slope indicator readings indicate stable conditions and no slope instability problems developed in 1987.

In general, wood chip insulated slopes have performed satisfactorily. Temperatures at the wood chip/ground interface have been gradually cooling since the first year when significant heat generation was noted (Table 1.1). Efforts to cool five locations with localized heating (hot spots) by removal and replacement of wood chips in order to expose the ground surface to ambient winter temperatures were successful. However, the three sites where wood chips were cooled simply by thinning or snow removal exhibited recurrence of warm temperatures in the summer of 1987. IPL plans to cool these areas by wood chip removal and by venting the wood chips.

In 1987, twenty-four previously monitored thaw settlement sites were surveyed. At virtually all sites, depth of permafrost was found to be in excess of 2.0 m (which was the probe length). Consequently, 1987 was the first year in which thawing had a potential to significantly contribute to differential settlement along the pipe. Where pipe elevations had apparently decreased, the average settlement was found to be about 0.05 m. Generally, apparent

settlement occurred over long transitions minimizing induced strains. While slight increases in strain were calculated for sites at Kp 1.5, 371.2, and 608.6, maximum recorded strain at these sites was only 0.27% (54% of design maximum).

While none of the monitored sites have developed strain values approaching the design maximum, all of the sites will continue to be monitored in 1988.

Frost heave strain gauges have been read each April. Calculations of principle stresses are all less than the yield strength of the pipe. Pipe thermistor data indicate that frost heave should not be a significant phenomenon under the current pipe temperature regime.

Aquatic Monitoring

Post-construction surveys of pipeline water crossings were conducted at least once per week beginning in April 1984. The purpose was to identify any physical conditions which could cause concern with respect to the integrity of the pipeline, or which might result in negative impacts to the aquatic resources or water quality along the pipeline route. These monitoring programs included several different studies.

Physical and chemical water quality parameters were monitored in the summer of 1985 at the Mackenzie River, Great Bear River, and Bosworth Creek pipeline crossings, all of which are used as domestic water sources. Results indicated that pipeline construction and operation had not impaired water quality at these watercourses one year after construction. No significant increases or decreases in any of the 20 chemical or physical parameters analyzed occurred downstream of the pipeline crossings relative to background levels recorded immediately upstream of the crossings.

The river bed profiles of the Mackenzie River and Great Bear River were surveyed annually. A comparison of the 1984 as-built profiles, with the 1985, 1986, and 1987 profiles indicates that there has been little change in the river beds at the pipeline crossings.

Detailed surveys were undertaken in July 1984, 1985, 1986, and 1987 during which all major (34 in total) and virtually all minor (182 in total) watercourses were examined in detail. Specifically, the approaches and instream ditchline were examined for stability (evidence of erosion, revegetation success), any pipeline-related alterations to the watercourse were evaluated, upstream and downstream areas were compared to evaluate potential sedimentation concerns, and the water crossings were assessed to determine whether the right-of-way was contributing to the degradation of water quality or aquatic habitat.

In general, very few problems were identified during the post-construction monitoring programs. Minor problems identified included subsidence of the ditch line on watercourse approaches and insufficient stream bank protection. Problem sites noted in 1984, 1985, and 1986 were corrected in winter restoration programs. Streambed monitoring revealed that in virtually all cases, sediments introduced to watercourses during winter instream construction activities were removed during the spring freshet. Long-term sediment introduction due to instability of water crossings, which is the primary concern in terms of aquatic habitat degradation, was not detected. This situation reflects both conscientious surveillance efforts and the success of remedial maintenance programs. Weekly surveillance of all pipeline water crossings will continue throughout the life of the pipeline.

Collectively, the IPL aquatic monitoring studies and those undertaken by Department of Fisheries and Oceans at Hodgson Creek (see Section

11. Aquatic Monitoring) indicate that efforts to minimize impacts to aquatic systems along the pipeline corridor have been successful. The data collected are consistent with a large volume of published literature on effects of pipeline construction on aquatic resources and support the conclusions of the Mackenzie Environmental Monitoring Project (MEMP) that effects are typically local and temporary and can be mitigated through proper design, construction, and maintenance procedures.

Raptor Monitoring

IPL participated in a cooperative raptor monitoring program with the Department of Renewable Resources, Government of the Northwest Territories (Matthews, 1987). IPL provided logistical support for an annual GNWT survey in which a total of 13 nesting areas were surveyed. IPL conducted pre-construction baseline surveys in 1980 and 1981, while the Government of the Northwest Territories conducted surveys from 1983 to 1987.

Forty-one nests were recorded in 1987 of which five were ledge nests and 36 were stick nests. Twelve of the 41 nests were occupied. In comparison, 39 nests were recorded in 1986 of which seven were ledge nests and 32 were stick nests. Nine of the 39 nests were occupied, an increase of four from the number recorded in 1985. In 1981, prior to pipeline development, only three of 44 nests were occupied (Table 1.2).

Peregrine falcons were observed at three nesting areas in 1987, 1986, and 1985 (Table 1.2) in comparison to sightings at two nesting areas in all other study years. Four active ledge nests were observed in these three nesting areas in 1987 and 1986, in comparison to one active ledge nest in 1985. In the seven years which raptor monitoring has been conducted, 1987 and 1986 were the only years in

which four nests were occupied and the only years in which all Peregrine Falcon nest sites along the pipeline route were occupied. The nine Peregrine young produced in 1987 also exceeded the productivity of all other monitored years. The second highest rate of productivity of all other monitored years was eight in 1986, and the third highest was five young produced in 1983, after the first year of construction.

Other nesting raptors in 1987 included six Golden Eagles, two Great Horned Owls, and ten Ravens.

Observations on non-nesting raptors in 1987 included seven individual sightings of Bald Eagles between Kp 447 and 527 along the Mackenzie River.

In comparing raptor observations and productivity from 1980 to 1987, (Table 1.4) it can be concluded that the activities associated with pipeline construction and operation, including ongoing helicopter patrols through nesting areas, have not significantly impacted raptor populations in the vicinity of the right-of-way.

Wildlife Monitoring

Wildlife monitoring studies were undertaken along the pipeline route from April 1985 to May 1987 to assess the effects of the pipeline right-of-way on local wildlife abundance, distribution, and local movements within and adjacent to the pipeline corridor. Study components included:

1. the identification of major habitats within the pipeline corridor, based on botanical characteristics, to aid in the interpretation of wildlife abundance and distribution data collected in the vicinity of the right-of-way (ROW);

2. track density surveys, designed to provide comparable estimates of furbearer track densities at various distances from the ROW;

3. browse utilization measurements (for hare and moose), designed to provide comparable estimates of browsing intensity at various distances from the ROW;

4. track monitoring on the ROW to assess the ROW crossing behaviour of various wildlife species;

5. aerial surveys, designed to provide comparable estimates of moose densities adjacent to and several km from the ROW;

6. the summarizing of track and wildlife observations recorded by Hunters and Trappers Association (HTA) members during snowmobile coverage of the ROW; and

7. the summarizing of wildlife sightings along the ROW by construction and pipeline surveillance personnel.

The study corridor for the project was arbitrarily defined as that area falling within 2 km of the pipeline. Several moose survey quadrats were located more than 2 km from the ROW to act as control areas. All remaining wildlife surveys were undertaken within the boundaries of the corridor.

During the first year of study, measurements of botanical composition and structure were collected within the pipeline corridor. Based on observed track densities and observations during aerial surveys, it was determined that black spruce bogs supported the lowest levels of wildlife activity of all the habitat types along the pipeline corridor. Therefore, it was concluded that the large majority of the pipeline corridor is situated in areas with inherently limited

capabilities for supporting wildlife.

Track surveys were conducted in those habitat types which had supported moderate to high levels of furbearer activity. To adequately sample these habitats, a series of transects were established at various distances from the edge of the ROW in the vicinity of the Wrigley pump station (Kp 335-347), the large burn south of Willowlake River (Kp 414-422), and Fort Simpson (Kp 429-547). All transects were surveyed in late November 1985 and again in early March 1986 and 1987.

Based on data collected during track surveys, hare was the most common furbearer residing in the pipeline corridor, followed by squirrel and mustelids (primarily marten) in that order. None of the furbearers demonstrated consistent positive or negative responses to undisturbed habitats adjacent to pipeline-related clearings, although the actual cleared areas appeared to be utilized less than undisturbed habitats. In addition, none of the species demonstrated higher activity levels within the pipeline corridor in low disturbance years (i.e. post-construction years), relative to mainline construction years.

Track densities were too low for other wildlife species to permit a detailed assessment of trends in abundance near the pipeline. Qualitatively, there was no indication that any of the less abundant furbearers were avoiding habitats immediately adjacent to the ROW or other facilities.

Browsing intensity by moose and hare was too low in all the sampled habitats to permit a proper assessment of browsing distributions in relation to the ROW on a habitat-specific basis (i.e. only 4% of 1217 sampled shrubs had signs of recent use by hare or moose). However, from an overview perspective of the data, the distribution of browse

sign by hare did not appear to demonstrate any avoidance of habitats adjacent to the ROW by this species, although 75% of moose sign fell more than 750 m from the ROW. In any case, the significance of ROW avoidance would be expected to be minimal, since browse availability is obviously not a factor limiting wildlife populations along the Mackenzie Corridor.

To assess the effects of the ROW on localized wildlife movements, patterns of mustelids (primarily marten), canids, caribou and moose encountering the ROW were collected during ground-based and aerial surveys (Table 1.3). Canids and caribou showed no aversion to the physical presence of the ROW, crossing it directly or using it as a travel corridor in the great majority of cases. Of the moose tracks observed approaching the ROW, 60% entered it, with approximately equal numbers of these tracks completing the crossing or retreating in the direction of their approach. Although 40% of the recorded tracks indicated no crossing attempt, most of these were observed more than 30 m from the ROW. Therefore, it is possible that the animals were simply foraging and were not aware of the ROW's presence. Thirty-three percent of all marten tracks sighted near the ROW did not enter it, while an additional seven percent followed the ROW for brief stretches before retreating.

Aerial surveys from fixed wing aircraft and helicopters were initiated in 1986 to provide additional data on moose numbers and distributions in the vicinity of the pipeline ROW. Since moderate to high moose densities were required for such comparisons, a reconnaissance flight along much of the ROW was used to subdivide the pipeline corridor (i.e., within 2 km of the ROW) into zones of low, medium and high moose activity.

Based on four fixed-wing reconnaissance flights flown over the central portion of the pipeline corridor (i.e., Kp 330-750), moose

densities along most of the pipeline corridor were found to be low (i.e. <0.1 moose/km^2). Furthermore, the reconnaissance flights indicated that moose numbers along the ROW transects were lower than those recorded along transects approximately 2 km from the ROW (Table 1.4). During the November 1985 reconnaissance flight, sufficient numbers of moose were sighted in the Jean Marie Creek area (Kp 550-580) and this area was selected for more intensive quadrat studies. Intensive aerial surveys of sample blocks, or quadrats four km by four km in size, were used to compare moose densities adjacent to and away from the ROW. Unlike the reconnaissance surveys, these more detailed surveys found that moose densities close to the ROW (0.16 moose/km^2) were not significantly different from those observed more than 2 km from the ROW (0.10 moose/km^2) (Table 1.5). In March 1986, a reconnaissance flight was unable to locate centres of moose activity and these intensive quadrat surveys were abandoned.

Members of the local HTAs were employed by IPL to provide information on wildlife use of the ROW (Table 1.6). The most common wildlife sign recorded by HTA personnel was that of large mustelids (primarily marten), followed by canids, moose, caribou, and lynx. This indicated that any aversion to the ROW by marten noted during observations of wildlife movement patterns was of limited significance.

Wildlife sightings along the ROW have been collected on an on-going basis by IPL surveillance personnel during weekly patrol flights. During the first two winters of pipeline operation, caribou were sighted most frequently, followed by moose, canids, large mustelids, and lynx. From a large mammal perspective, the stretch of pipeline from Kp 585 - 790 supported the highest level of wildlife activity in winter. During the first two summers of pipeline operation, black bear was the most common wildlife species sighted, followed by caribou, moose, and canids. No centres of wildlife activity along the ROW were apparent during the summer periods. Of the major

wildlife observations recorded by surveillance personnel, only black bear sightings increased noticeably from 1986 to 1987. The great majority of bear sightings have been recorded in May and June of each year, suggesting that the grass cover of the ROW is providing the bears with an attractive forage source immediately after their denning period.

In summary, the construction and operation of the Norman Wells pipeline has not significantly altered the abundance, distribution, or local movements of wildlife within the pipeline corridor. During periods of mainline construction, pipeline-related disturbance likely resulted in a minor displacement of animals from the immediate vicinity of the ROW, but comparative pre-construction data are not available to confirm this suggestion. Based on survey data collected to date, there is no evidence that such displacement has persisted for furbearers. Although there is some indication that moose numbers are lower in habitats immediately adjacent to the ROW (i.e. within 1 km), relative to comparable habitats more removed from the pipeline, this impact is not considered to be of significance, either on a local or regional scale, given the small number of animals potentially affected and the localized zone of impact. In addition, the Mackenzie Highway and winter road which closely parallel the pipeline north of Fort Simpson undoubtedly influence animal distributions, and the impacts from the two linear facilities cannot easily be separated.

From a habitat perspective, the pipeline ROW offers an alternative habitat structure from adjacent, undisturbed areas. For the smaller, territorial furbearers, the 25 m wide ROW, with its open herbaceous cover, currently represents less favourable habitat than denser shrub or forest cover. The ROW, in its present state, also appears to be discouraging, but not eliminating, the cross ROW movements of some of the smaller furbearers. However, this barrier effect should diminish

as vegetative cover increases over much of the width of the ROW.

For larger mammals, the ROW represents a more positive habitat alteration. Because it is cleared of dense vegetation and seldom maintains deep accumulations of snow, it serves as an attractive corridor for inter-range travel and perhaps long-range dispersal. Through revegetation efforts of IPL, the ROW currently supports a productive forage source (i.e. grasses) not readily found in adjacent undisturbed areas. In the next several years, it will also be colonized by natural and palatable browse species over much of its area.

The ROW also provides a new travel corridor for ATV and snowmobile traffic, and is currently used by hunters and trappers. However, few remote areas are accessed by the ROW, and local hunting and trapping distribution patterns should not significantly change as a result of the pipeline.

Collectively, the survey data indicate that the pipeline development has had neither positive nor negative impacts on the wildlife populations along the corridor. It appears that the ROW is a habitat of limited significance to local wildlife, an observation which concurs with the conclusions of MEMP and a considerable amount of literature regarding pipeline development impacts on northern wildlife resources.

Revegetation Monitoring

Detailed revegetation monitoring surveys were undertaken in late August and early September in 1984, 1985, 1986, and 1987.

By means of an aerial survey, plant cover was assessed in qualitative terms along the right-of-way and associated construction sites. One

hundred and fifty-six permanently marked transects were monitored to provide a quantitative assessment of vegetation cover. Sites selected for quantitative vegetation monitoring included: all major terrain types; areas where full, partial, or no seeding was undertaken; major slopes; off right-of-way sites; and areas which received special treatments including 20 revegetation trial sites established in cooperation with the Department of Indian Affairs and Northern Development to test the effectiveness of seeding and/or fertilization.

Revegetation results to 1987 were favourable. Total plant cover on areas first seeded in 1984 averaged 72% in 1987, similar to the 1986 average (Tables 1.7, 1.8). On areas first seeded in 1985, total plant cover averaged 55% in 1987, slightly higher than the previous year's 49%. Two to three fifths of the total plant cover was grass litter. Living cover was approximately two-thirds seeded grasses and one-third native vascular plants.

The distribution of plant cover among seeded construction sites varied considerably in 1987 from 67% on the ROW to 100% on campsites and spoil sites. Total plant cover generally remained similar to that recorded in 1986.

Boreal creeping red fescue continued to provide the most ground cover in 1987, accompanied on drier sites (backfilled ditch line materials, coarse soils) by Revenue slender wheatgrass and Sheep fescue. Creeping foxtail was the dominant seeded species in moist areas while Reed canary grass was locally abundant in wet areas. Climax timothy was still present but has declined substantially in abundance over the past two years.

Total cover on the Revegetation Trial Sites in 1987 was generally similar to that recorded in 1986 (Tables 1.7, 1.8). In 1987, total

cover was still highest on plots which received both seed and fertilizer (67%). Total cover on plots which were not seeded or fertilized was generally approaching that where both seed and fertilizer were applied; however, the data indicate that only seed and fertilizer produce cover capable of providing adequate erosion protection in the first two years following disturbance.

Unlike areas of mineral soils, areas of organic terrain were not seeded or fertilized after construction. In recognition of the low erosion potential on these areas of level gradient and their limited habitat values, the approach to reclamation was to allow areas of organic terrain to revegetate through natural processes. However, concern has been expressed at the slow rate of vegetation recovery on these lands.

In response, in the summer of 1987, IPL initiated two revegetation trials on organic terrain: between Kp 83 and 88 (peat veneer over lacustrine plain), and Kp 679 (bog terrain). Both sites had experienced winter pipeline construction in 1984 but neither had been seeded or fertilized subsequently.

The Kp 88 site received much greater precipitation in 1987 than fell at Kp 678. Analysis of composite surface soils collected in June also indicated that site Kp 88 presented more favourable conditions for plant growth than Kp 678.

Vascular plant cover at Kp 678 ranged from 3 to 7% and 2 to 11% in the unseeded and seeded plots, respectively (Table 1.9). These data are comparable to first year revegetation cover values realized at Revegetation Trial Sites established in 1984 and 1985. The fertilizer blended for the construction revegetation program (17-25-15) applied at 500 kg/ha produced the greatest vascular plant cover in both seeded and unseeded plots. The high phosphorous

fertilizer at the high application rate (10-34-10 at 1000 kg/ha) produced results similar to the construction fertilizer at 250 kg/ha.

Vascular plant cover at Kp 88 ranged from 17 to 28% in unseeded plots and 29 to 43% in seeded plots (Table 1.9). These are among the best first year results along the ROW to date (Tables 1.7, 1.8). The construction fertilizer at 500 kg/ha and the high phosphate fertilizer at 250 and 1000 kg/ha all produced similar vascular plant cover (26 to 28%) in unseeded plots. The greatest cover in seeded plots was produced with high phosphate fertilizer at the high rate of application (10-34-10 at 1000 kg/ha). Vascular cover in other treatments ranged from 26 to 33% while the control plots had a mean ground cover of 20%. Native vascular species most commonly found at Kp 88 included Carex spp, Arctagrostis latifolia, and Equisetum spp. Non-vascular plant cover was absent in the seeded plots and only present, with low cover values, in unseeded plots.

The most successful species at both sites included Vantage Reed canary grass, Climax timothy, and Common violaceum (Table 1.10). Garrison creeping foxtail was more successful at Kp 678 (18% vs. 6%) while Big Horn Sheep fescue (15% vs. 8%) and Common fowl bluegrass (15% vs. 2%) were more successful at Kp 88. The annual cereal crops produced cover values ranging from 6% (Kodiak fall rye) to 11% (Cascade oats). The performance of the species may have been reduced, particularly at Kp 88, by the presence of non-seeded vascular species in the trial plots averaging 8% at Kp 88 and 1% at Kp 678.

These data suggest that it is possible to produce considerable vegetative cover in the first year after seeding organic soils.

IPL also undertook a program to test the effectiveness of shrub cuttings to improve terrain stability at selected locations along the

ROW. Of the 1033 cuttings planted in the spring of 1985, only 425 or 41% were surviving in August 1986. While no monitoring of these sites was done in 1987, it is apparent that the shrubs will not significantly contribute to terrain stability for several years.

Collectively, data from the vegetation monitoring programs provide evidence that establishment of an effective cover in boreal and subarctic environments is not problematic and can be accomplished in one to two growing seasons.

Aerial Photography and Analysis

An aerial photography program has been underway since 1980 to provide a permanent chronological record of terrain and landscape conditions before, during, and after construction. Aerial photographs were taken by IPL in 1980 and by Indian and Northern Affairs Canada annually from 1983 to 1985.

In July 1986, Interprovincial Pipeline undertook black and white panchromatic photography of the entire pipeline right-of way at a scale of 1:10,000. Colour photography also was taken at 29 selected sites at a scale of 1:4000. An analysis of ground conditions on the right-of-way as shown on the photographs was then conducted. Specifically, the analysis provided a log, by kilometer post, of vegetation cover and type and major physical disturbances such as ground settlement, erosion features, slides, and ditch line settlement. Results from the analyses have been included elsewhere in this report. IPL will again produce an aerial photographic record in the summer of 1988.

Conclusions/Recommendations

The results of the post-construction monitoring programs indicate that no significant environmental impacts have resulted to date from pipeline construction or operations. Since initiation of construction, no significant variance from predicted performance has been observed with respect to terrain performance, aquatic resources, raptor populations, wildlife resources, or revegetation success. Conscientious monitoring and surveillance programs will continue to ensure that any terrain instability is rapidly identified and to allow for early restorative works where required.

Recommendations that can be drawn from the results of these monitoring programs regarding future northern pipeline development are:

1. Since monitoring data indicate stable terrain conditions and minimal impacts on wildlife and aquatic resources resulting from construction and operation of the Norman Wells pipeline, it would be prudent to implement environmental protection measures similar to those employed on this project. These protection measures include careful route selection, development of appropriate pipeline designs and activity-specific mitigation plans, on-site supervision during construction, and routine post-construction monitoring and maintenance activities.

2. No further quantitative studies regarding effects of pipeline construction and operation on wildlife or aquatic resources are recommended for future northern pipeline development in similar habitats. Current knowledge of northern wildlife and aquatic systems supported by literature and monitoring data are available to predict that impacts will be minor, localized, and temporary.

3. Since efforts to produce effective vegetative cover along the Norman Wells pipeline ROW were successful and have enhanced terrain stability, similar revegetation efforts should be afforded future northern pipeline developments.

4. Revegetation of northern pipeline rights-of-way does not appear problematic in the short-term; therefore, revegetation research should focus on long term (i.e. more than 10 years) results.

Proposed Follow-up Post Construction

Interprovincial has now concluded many of the monitoring programs but will continue with the established programs to the dates shown on Table 1.11.

Reports Available

Reports are available for viewing at the Interprovincial Pipe Line office in Edmonton, Alberta. Copies are also available for viewing at DIAND, Yellowknife, NWT; GNWT, Yellowknife, NWT; NEB, Ottawa, Ontario; Boreal Institute, Edmonton, Alberta; and Arctic Institute, Calgary, Alberta.

Raptor Monitoring

Ealey, D.M. 1982. Raptor survey along the Norman Wells Pipeline route, 1981. Prepared by McCourt Management Ltd. for Interprovincial Pipe Line (NW) Ltd.

Ealey, D.M. and R.H. McCourt. 1980. Raptor survey along the proposed pipeline route from Norman Wells, NWT to Zama Lake, Alberta, August 15-18, 1980. Prepared by McCourt Management Ltd. for Interprovincial Pipe Line (NW) Ltd.

Matthews, S.B. 1984. Raptor monitoring program Norman Wells Pipeline Project, 1984 progress report. Department of Renewable Resources, Government of the Northwest Territories.

Matthews, S.B. 1985. Raptor monitoring program Norman Wells Pipeline Project, 1985 progress report. Department of Renewable Resources, Government of the Northwest Territories.

Matthews, S.B. 1986. Raptor monitoring program Norman Wells Pipeline Project, 1986 progress report. Department of Renewable Resources, Government of the Northwest Territories.

Matthews, S.B. 1987. Raptor monitoring program Norman Wells Pipeline Project, 1987 progress report. Department of Renewable Resources, Government of the Northwest Territories.

Wildlife Monitoring

Ealey, D.M. 1982. Inspection of wildlife habitat at facility sites along the Norman Wells pipeline. Prepared by McCourt Mgt. Ltd. for Interprovincial Pipe Line (NW) Ltd.

Ealey, D.M. and F.E. Geddes. 1982 Wildlife habitat survey of borrow pit sites and facility sites along the Norman Wells pipeline, 23 June to 7 July, 1982. Prepared by McCourt Mgt. Ltd. for Interprovincial Pipe Line (NW) Ltd.

Eccles, D.M., R.G. Searing, J. Duncan and C. Thompson. 1985. Wildlife monitoring studies along the Norman Wells - Zama Oil pipeline January - March 1985. Prepared by LGL Limited.

Eccles, D.M. and J.A. Duncan. 1986. Wildlife monitoring studies along the Norman Wells - Zama Oil pipeline April 1985 to May 1986. Prepared by Delta Environmental Management Group Ltd.

Eccles, D.M. and J.A. Duncan. 1987. Wildlife monitoring studies along the Norman Wells - Zama Oil pipeline November 1984 to May 1987. Prepared by Delta Environmental Management Group Ltd. for Interprovincial Pipe Line (NW) Ltd.

Geddes, F.E. and J.A. Duncan. 1982. Late winter moose surveys along the Mackenzie River and Norman Wells pipeline route. Prepared by McCourt Mgt. Ltd. for Interprovincial Pipe Line (NW) Ltd.

Aquatic Monitoring

Aquatic Environments Ltd. 1982. Late winter surveys along the IPL pipeline route, Norman Wells NWT to Zama Terminal Alberta. Prepared for Interprovincial Pipe Line (NW) Ltd.

Aquatic Environments Ltd. 1982. A survey of facility sites in relation to aquatic habitats along the IPL pipeline route Norman Wells, NWT to Zama Terminal Alberta. Prepared for Interprovincial Pipe Line (NW) Ltd.

Aquatic Environments Ltd. 1982. An assessment of the fisheries resources of the Great Bear and Mackenzie Rivers in the vicinity of the proposed IPL Pipeline crossing. Prepared for Interprovincial Pipe Line (NW) Ltd.

Fernet, D.A. 1984. Fisheries and water quality monitoring in relation to an instream blast in the Mackenzie River. Prepared by Environmental Management Associates.

Fernet, D.A. 1984. Aquatic monitoring, July, 1984. Norman Wells to Zama Pipeline. Prepared by Environmental Management Associates.

Fernet, D.A. 1985. Aquatic monitoring survey, Norman Wells to Zama Pipeline, July 1985. Prepared by Environmental Management Associates.

Fernet, D.A. 1986. Aquatic monitoring survey, Norman Wells to Zama Pipeline, July 1986. Prepared by Environmental Management Associates.

Fernet, D.A. 1987. Aquatic monitoring survey, Norman Wells to Zama Pipeline, July 1984-1987. Prepared by Environmental Management Associates for Interprovincial Pipe Line (NW) Ltd..

Interprovincial Pipe Line (NW) Ltd. 1984. Water quality monitoring in relation to pipeline construction across Bosworth Creek, NWT.

Interprovincial Pipe Line (NW) Ltd. 1984. Water quality monitoring in relation to 1984 pipeline construction.

Interprovincial Pipe Line (NW) Ltd. 1984. Mackenzie River pipeline crossing, Water Licence N3L6-1126, 1983 annual monitoring and surveillance report.

Interprovincial Pipe Line (NW) Ltd. 1984. Great Bear River pipeline crossing, Water Licence N2L6-1126, 1983 annual monitoring and surveillance report.

Interprovincial Pipe Line (NW) Ltd. 1985. Water quality monitoring in relation to 1985 pipeline construction and operation.

Interprovincial Pipe Line (NW) Ltd. 1985. Mackenzie River pipeline crossing, Water Licence N3L6-1126, 1984 annual monitoring and surveillance report.

Interprovincial Pipe Line (NW) Ltd. 1985. Great Bear River pipeline crossing, Water Licence N2L6-1126, 1984 annual monitoring and surveillance report.

Interprovincial Pipe Line (NW) Ltd. 1986. Mackenzie River pipeline crossing, Water Licence N3L6-1126, 1985 annual monitoring and surveillance report.

Interprovincial Pipe Line (NW) Ltd. 1986. Great Bear River pipeline crossing, Water Licence N2L6-1126, 1985 annual monitoring and surveillance report.

Interprovincial Pipe Line (NW) Ltd. 1987. Mackenzie River pipeline crossing, Water Licence N3L6-1126, 1986 annual monitoring and surveillance report.

Interprovincial Pipe Line (NW) Ltd. 1987. Great Bear River pipeline crossing, Water Licence N2L6-1126, 1986 annual monitoring and surveillance report.

Revegetation Monitoring

Hardy Associates (1978) Ltd. 1984. 1984 Revegetation monitoring of the Interprovincial Pipe Line (NW) Ltd. Norman Wells to Zama Pipeline.

Hardy Associates (1978) Ltd. 1985. 1985 Revegetation monitoring of the Interprovincial Pipe Line (NW) Ltd. Norman Wells to Zama Pipeline.

Hardy Associates (1978) Ltd. 1985. Norman Wells to Zama Pipeline revegetation program - shrub cutting trial - 1985.

Hardy Associates (1978) Ltd. 1985. Norman Wells to Zama Pipeline, July 1985 revegetation program.

Hardy BBT Ltd. 1986. 1986 Revegetation monitoring of the Interprovincial Pipe Line (NW) Ltd. Norman Wells to Zama Pipeline.

Hardy BBT Ltd. 1987. 1987 Revegetation monitoring of the Interprovincial Pipe Line (NW) Ltd. Norman Wells to Zama Pipeline.

Hardy BBT Ltd. 1987. Norman Wells pipeline, organic terrain revegetation trials.

Interprovincial Pipe Line (NW) Ltd. 1986. Norman Wells Pipeline Project Revegetation Activities February to March, 1986 and July, 1986.

UMA. Canuck. Hardy. 1984. Revegetation program, March - April 1984. Prepared for Interprovincial Pipe Line (NW) Ltd.

UMA. Canuck. Hardy. 1985. Interprovincial Pipe Line (NW) Ltd. Norman Wells to Zama Pipeline revegetation activities, March April 1984 and February - March 1985.

Waterfowl

Geddes, F.E. and K.H. McCourt. 1982. Waterfowl migration surveys along the Mackenzie River, spring 1981. Prepared for Interprovincial Pipe Line (NW) Ltd.

Geddes, F.E. and J.A. Duncan. 1983. Waterfowl migration surveys along the Mackenzie River, spring 1982. Prepared for Interprovincial Pipe Line (NW) Ltd.

General

Hardy BBT Ltd. 1986. Interpretation of aerial photographs Norman Wells to Zama Pipeline.

Interprovincial Pipe Line (NW) Ltd. 1983. Norman Wells Pipeline Project 1983 report on monitoring of construction and operation.

Interprovincial Pipe Line (NW) Ltd. 1984. Norman Wells Pipeline Project 1984 report on monitoring of construction and operation.

Interprovincial Pipe Line (NW) Ltd. 1984. Post construction monitoring program for the Norman Wells to Zama Pipeline.

Interprovincial Pipe Line (NW) Ltd. 1985. Norman Wells Pipeline Project 1985 report on monitoring of construction and operation.

Interprovincial Pipe Line (NW) Ltd. 1986. Norman Wells Pipeline Project 1986 report on monitoring of construction and operation.

Interprovincial Pipe Line (NW) Ltd. 1987. Norman Wells Pipeline Project 1987 report on monitoring of construction and operation.

Contact

Mr. Donald M. Wishart

Interprovincial Pipe Line (NW) Ltd.

Box 398

Edmonton, Alberta T5J 2J9

(403) 420-5210

Table 1.1 Cooling trend at base of wood chips

	1st Thaw Season	2nd Thaw Season	3rd Thaw Season	4th Thaw Season
No. of Data	19	19	19	9
Temp. Range	+4.5 to -0.5	+1.9 to -0.8	+0.7 to -0.6	+0.5 to -0.6
Average Temperature	+0.7	+0.2	-0.1	0.2

Table 1.2 Summary of Raptor observations along pipeline right-of-way 1980 - 1986

Nesting Area	Year of Survey 1980	1981	1983	1984	1985	1986	1987
A	2[1] GE[2]-ad[3] 1 GE-imm	2 AK-ad	2 PF-ad 1 PF-imm	2 PF-ad 1 PF-imm	2 PF-ad 3 PF-yg 2 Rav-ad 3 Rav-yg	2 PF-ad 3 PF-yg 4 Rav-ad	2 PF-ad 2 PF-yg 2 GE-ad 1 GE-yg 2 GHO-yg
B	0	1 GE-ad	2 Rav-ad	2 Rav-ad 3 Rav-yg 2 RT-ad 2 RT-yg	0	1 RT-ad 2 Rav-ad	2 GE ad 2 GE-yg 2 Rav-yg
C	1 PF-ad 1 PF-imm	2 PF-ad 1 PF-imm	1 PF-ad 4 PF-imm	2 PF-ad 1 GE-ad 1 GE-imm	2 PF-ad 2 GE-ad 1 GE-yg	4 PF-ad 2 PF-yg 2 GE-ad 1 GE-yg	4 PF-ad 5 PF-yg[5] 2 GE-ad 1 GE-yg 2 Rav-yg[5]
D	0	0	1 GHO-ad 1 GHO-yg	0	2 GHO-ad	0	1 PF-ad
E	1 PF-imm	1 PF-ad 4 PF-yg	1 RT-ad 2 RT-yg	2 PF-ad 1 GE-ad 1GE-yg	2 PF-ad	2 PF-ad 3 PF-yg	2 PF-ad 3 PF-yg 2 Rav-yg[5]
F	0	1 RT-ad 3 Rav-undet		2 Rav-ad 3 Rav-yg	1 Rav-ad 3 Rav-yg	2 Rav-ad	2 Rav-yg
G	1 GE-ad 1 GE-imm	1 GE-ad	0	0	0	1 AK-ad	2 GE-ad 1 GE-yg
H	0	0	0	0	0	0	0
I	0	1 AK-ad	2 GE-ad 2 GE-yg	2 GE-ad 1 GE-yg	2 GE-ad	2 GE-ad 2 GE-yg	2 GE-ad 1 GE-yg
J	0	1 Rav-undet					0
K	0	0	0	0	0	0	0
L	- [4]	- [4]	0	0	0	0	0
M	1 BE-ad 3 BE-imm	0	1 BE-ad 1 GE-ad	0	0	0	2 BE-ad 1 BE-yg

1 Number of birds observed in or near the nesting area of species and age indicated.
2 Species of raptor observed: GE Golden Eagle; BE Bald Eagle; PF Peregrine Falcon; AK American Kestrel; RT Red Tailed Hawk; Rav Raven; GHO Great Horned Owl
3 Age of bird: ad adult; imm-immature; yg-young (nestling); undet-undetermined age
4 Nesting area not surveyed in 1980 or 1981.
5 Exact number of young unknown.

Table 1.3 Summary of observed wildlife responses to the ROW during the IPL wildlife monitoring studies (1985-87)

Species	Apparent No. of Animals Involved	Frequency of Approaches to the ROW during crossing attempt [No.(%)][1]				Synthesis of Crossing Details for all Approaches				
		1	2	3	Unknown	Direct[1] Crossing	Deflected[2] Crossing	Deflected[3] No Crossing	No Crossing[4] Attempt	Unknown[5]
Mustelids (ground obs.)	49	44(90%)	4(8%)	1(2%)	0	27(49%)	6(11%)	4(7%)	18(33%)	0
Mustelids (aerial obs.)	36	0	0	0	36(100%)	33(91.6%)	0	1(2.8%)	1(2.8%)	1(2.8%)
Canids (all obs.)	41	32(78%)	3(9%)	0	6(15%)	7(16%)	10(23%)	18(41%)	1(2%)	8(18%)
Caribou (all obs.)	65	65(100%)	0	0	0	28(43%)	21(32%)	14(22%)	2(3%)	0
Moose (all obs.)	33	29(88%)	2(6%)	0%	2(6%)	6(17%)	5(14%)	10(29%)	14(40%)[6]	0

[1] Direct crossing - animal crosses ROW roughly at right angles.

[2] Deflected crossing - animal follows along ROW before completing the crossing.

[3] Deflected, no crossing - animal follows along ROW, then exits ROW on the side of its approach.

[4] No crossing attempt - animal approaches but does not enter the ROW.

[5] "Unknown" refers to tracks sighted on the ROW for which crossing details are not known.

[6] In 8 out of the 14 sightings, the animal remained more than 30 m from the ROW, and was likely unaware of its presence.

Table 1.4 Moose observed during wildlife reconnaissance flights (1984/87)

Date	Flight Coverage	Moose Observed from ROW Transects				Moose Observed from Control Transect			
		On-Trans	(no./km²)	Off-Trans	Total	On-Trans	(no./km²)	Off-Trans	Total
Nov. 22/85	Kp 529-684	4	(0.06)	0	4	3	(0.05)	0	3
Nov. 27/85	Kp 330-529	0	(0)	0	0	2	(0.03)	0	2
Mar. 17/86	Kp 529-750	0	(0)	0	0	3	(0.03)	1	4
Nov. 23/86	Kp 529-750	0	(0)	0	0[1]	5	(0.06)	0	5[2]
Nov. 5/86	Kp 336-529	0	(0)	2	2[3]	1	(0.01)	0	1
Mar. 7/87	Kp 529-750	2	(0.02)	1	3[4]	7	(0.08)	2	9
Mar. 7/87	Kp 336-529	0	(0)	2	2	3	(0.04)	1	4
TOTALS		6	-	5	11	24	-	4	28

[1] Twelve caribou sighted on transect

[2] Three caribou sighted on transect

[3] One caribou sighted off transect

[4] Five caribou sighted off transect

Table 1.5 Moose densities observed during quadrat surveys in the Jean Marie Creek area (November 1985)

Quadrats Within 1 km of ROW			
Quadrat	Area (km^2)	No. Moose	Density (No./km^2)
1	3.6	0	0
2	4.9	0	0
3	4.6	0	0
6	3.7	2[1]	0.54
7	3.3	2[1]	0.61
12	4.1	0	0
13	4.0	2[1]	0.50
16	3.4	0	0
18	4.5	0	0
19	4.0	0	0
TOTAL	40.1	6	$\bar{x}$ = 0.16

Quadrats ≥ 2 km from ROW			
Quadrat	Area (km^2)	No. Moose	Density (No./km^2)
4	3.6	0	0
5	4.6	0	0
8	4.5	0	0
9	4.0	1[2]	0.50
10	5.7	0	0
11	5.6	0	0
14	4.4	0	0
15	3.9	2[1]	0.51
17	4.0	0	0
20	4.0	0	0
TOTAL	44.3	3	$\bar{x}$ = 0.10

[1] - cow/calf pair
[2] - bull

Table 1.6 Synthesis of HTA observations of wildlife and/or tracks along portions of the ROW (December 1984 - March 1987)

ROW Segment	Total Survey Km	Moose #(#/km)	Caribou #(#/km)	Canid #(#/km)	Large[1] Mustelid #(#/km)	Small[2] Mustelid #(#/km)	Lynx #(#/km)	Squirrel #(#/km)	Hare #(#/km)
Norman Wells to Ft. Norman (kp 0-80)	464.5	8(0.02)	-	7(0.02)	24(0.05)	NQ	12(0.03)	-	NQ
Ft. Norman to Saline River (kp 80-180)	1054	23(0.02)	-	5(*)	57(0.05)	6(*)	14(0.01)	10(*)	NQ
Saline River to Blackwater River (kp 180-224)	156[5]	7(0.04)	19(0.12)	3(0.02)	40(0.26)	8(0.05)	16(0.10)	8(0.05)	22(0.14)
Blackwater River to Wrigley (kp 224-330)	1254	54(0.04)	83(0.07)	38(0.03)	322(0.26)	53(0.04)	85(0.07)	51(0.04)	808(0.64)
Wrigley to Willowlake River (kp 330-381)	207[6]	-	2(*)	10(0.05)	125(0.60)	10(0.05)	13(0.06)	116(0.56)	982(4.74)
Willowlake River to Camsell Bend (kp 381-447)	1293	110(0.09)	40(0.03)	230(0.18)	459(0.35)	-	46(0.03)	-	NQ
Camsell Bend to Mackenzie River Crossing (kp 447-528)	1081	45(0.04)	58(0.05)	17(0.02)	70(0.06)	NQ	18(0.02)	NQ	NQ
Mackenzie River Crossing to Mackenzie Highway Crossing (kp 529-585)	808	22(0.03)	-	41(0.05)	276(0.34)	NQ	10(0.01)	NQ	NQ
Mackenzie Highway Crossing to Trout River Region (kp 585-665)	440	8(0.02)	20(0.05)	-	85(0.19)	-	3(*)	-	NQ
Trout River Region to kp 774 (kp 665-774)	592[6]	24(0.04)	67(0.11)	1(*)	268(0.45)	-	4(*)	-	-
TOTALS	7349.5	301(0.04)	289(0.04)	355(0.05)	1726(0.23)	-	221(0.03)	-	-

1 Large mustelid refers to marten, mink, wolverine, and otter.
2 Small mustelid refers to ermine and least weasel.
3 NQ - not quantitative. Animal sign recorded in a qualitative fashion.
4 NW - not sampled.
5 Sampled in first winter only.
6 Sampled in second and third winters only.
* Densities less than 0.01.
- No observations recorded.

Table 1.7 Mean Percentage Plant Cover Along Permanent Transects on Areas Seeded in Winter 1984

SITES	SEEDED COVER				NATIVE COVER				LITTER COVER				TOTAL COVER			
	1984	1985	1986	1987	1984	1985	1986	1987	1984	1985	1986	1987	1984	1985	1986	1987
R.O.W.																
Overland	13	18	32	20	6	9	15	8	0	1	27	41	19	28	74	69
Slopes	17	21	30	15	5	9	13	11	0	5	27	40	22	35	70	66
All	15	20	31	18	6	9	14	9	0	3	27	40	21	32	72	67
R.O.W.																
Organic	0	1	1	0	4	8	16	16	0	0	0	0	4	9	17	16
Borrow Sites	11	10	18	12	1	4	9	8	0	1	9	11	12	15	36	31
Spoil Sites	13	25	49	36	1	2	8	15	0	8	35	41	14	35	92	92
Campsite	5	26	38	37	7	20	18	28	0	4	21	41	12	50	77	106*
Wood Harvest Sites																
Not seeded	0	0	0	0	10	23	30	38	0	0	0	0	10	23	30	38
Revegetation Trial Sites																
NS/NF	0	1	1	1	7	15	35	30	0	0	2	7	7	16	38	38
Seed Only	5	6	14	19	10	19	31	16	0	0	13	36	15	25	58	71
Fert. Only	1	1	1	2	12	25	50	36	0	0	4	11	13	26	55	49
Seed + Fert.	13	21	28	21	8	11	16	9	0	1	25	39	21	33	69	69

* indicates multi-storey plant cover

Table 1.8 Mean Percentage Plant Cover Along Permanent Transects on Areas Seeded in Winter 1985

SITES	SEEDED COVER			NATIVE COVER			LITTER COVER			TOTAL COVER		
	1985	1986	1987	1985	1986	1987	1985	1986	1987	1985	1986	1987
R.O.W.												
Overland	12	25	19	6	13	12	0	6	18	18	44	49
Slopes	14	28	20	2	4	16	0	17	33	16	49	69
All	13	26	19	4	10	12	0	10	21	17	46	52
Campsite	7	46	31	2	0	0	0	42	70	9	88	101*
Wood Harvest Sites												
Not seeded	0	0	0	13	39	41	0	0	0	13	39	41
Revegetation Trial Sites												
NS/NF	0	2	2	6	12	14	0	0	1	6	14	17
Seed Only	5	11	12	4	10	11	0	1	8	9	22	31
Fert. Only	0	3	13	9	26	22	0	0	6	9	29	41
Seed + Fert.	11	23	19	6	13	12	0	4	18	17	40	49

* indicates multi-storey plant cover

Table 1.9 First Year Percentage Plant Cover in Fertilizer Trial Plots in Peat Soils Near Kp 678 and Kp 88.

Treatment	Non-Vascular Species	Seeded Species	Native Vascular Species		Total Vascular Species
			Herbaceous	Shrubs	
Kp 678					
A. Not Seeded					
17-25-15 @ 250 kg/ha	13	0	2	1	3
17-25-15 @ 500 kg/ha	15	+	6	1	7
10-34-10 @ 250 kg/ha	13	0	2	1	3
10-34-10 @ 500 kg/ha	7	+	4	2	6
10-34-10 @ 1000 kg/ha	2	0	3	1	4
Control	8	0	3	+	3
B. Seeded					
17-25-15 @ 250 kg/ha	9	6	2	1	9
17-25-15 @ 500 kg/ha	5	9	1	1	11
10-34-10 @ 250 kg/ha	3	3	2	+	5
10-34-10 @ 500 kg/ha	8	5	2	+	7
10-34-10 @ 1000 kg/ha	1	6	2	+	8
Control	3	1	1	+	2
Kp 88					
A. Not Seeded					
17-25-15 @ 250 kg/ha	2	0	12	8	20
17-25-15 @ 500 kg/ha	0	0	14	13	27
10-34-10 @ 250 kg/ha	+	0	17	11	28
10-34-10 @ 500 kg/ha	0	0	12	8	20
10-34-10 @ 1000 kg/ha	0	0	17	9	26
Control	0	0	10	7	17
B. Seeded					
17-25-15 @ 250 kg/ha	0	24	2	+	26
17-25-15 @ 500 kg/ha	0	25	5	+	30
10-34-10 @ 250 kg/ha	0	22	5	1	28
10-34-10 @ 500 kg/ha	0	25	6	1	33
10-34-10 @ 1000 kg/ha	0	39	3	1	43
Control	0	16	3	1	20

+ present at <1% cover

Table 1.10 First Year Percentage Cover in Species Trials in Peat Soil Near Kp 678 and Kp 88

Seeded Species	Kp 678	Kp 88	Average
Climax timothy	8	15	13
Vantage reed canary grass	26	15	21
Garrison creeping foxtail	18	6	12
Big Horn sheep fescue	8	15	13
Triana hard fescue	7	8	8
Common fowl bluegrass	2	13	8
Common Canada bluegrass	4	6	5
Common violaceum	14	13	14
Highland colonial bentgrass	3	8	6
Prominent creeping bentgrass	2	5	4
Cascade oats	7	11	9
Kodiak fall rye	6	6	6

Table 1.11 Schedule of post-construction monitoring programs

PROGRAM	INITIATE	TERMINATE	FREQUENCY
STANDARD OPERATIONAL MONITORING			
Aerial Surveillance	1984	Lifetime*	Weekly
Ground Inspection	1984	Lifetime*	Annual
GEOTECHNICAL MONITORING			
Thaw Settlement	1984	Lifetime**	Annual
Frost Heave	1984	Lifetime**	Four/year
Slope Performance	1984	Lifetime**	Eight/Year
AQUATIC MONITORING			
Mackenzie and Great Bear	1985	Lifetime*	Annual
All Watercourses	1984	Lifetime*	Weekly
RAPTOR MONITORING	1983	1987	Annual
WILDLIFE MONITORING			
Right-of-way Monitoring	1984	1988	Weekly
Transect Monitoring	1984	1987	Bi-annual
REVEGETATION MONITORING			
Aerial Survey	1984	Lifetime*	Weekly
Baseline Data Collection	1984	1985	Annual
Permanent Sample Transects	1984	1987	Annual
Revegetation Trial Sites	1984	1987	Annual
AERIAL PHOTOGRAPHY AND GROUND TRUTHING	1986	1988	Biennial

* "Lifetime" refers to operational lifetime.
** Program may be discontinued if history of readings indicates an equilibrium situation.

2. ENVIRONMENTAL BASELINE STUDIES

Agency Responsible

Esso Resources Canada Limited

Start-up Date

Summer 1984

Objectives

Esso Resources, on its own initiative, set up an environmental baseline and monitoring program during the summer of 1984, prior to project start-up. The intent of the study was to collect sufficient environmental data to:

1. aid environmental policy and management decisions;
2. identify and define environmental problems; and
3. measure environmental impacts.

Locations

Norman Wells

Results to Date

Water Quality

In 1984, water samples were collected in Bosworth Creek at the IPL crossing, in the reservoir, and at the mouth. Samples were analyzed for basic water chemistry as well as the presence of selected organic chemicals, heavy metals, and inorganic chemicals.

Sediment Analysis

Sediment samples were collected at four locations in Bosworth Creek. The general physical and chemical characteristics of the sediments were determined.

Fish Quality

Arctic grayling were collected in the headwaters of Bosworth Creek and in Bosworth Creek reservoir in July 1984. Samples were analyzed for mixed-function-oxidase activity by the Department of Fisheries and Oceans. There seemed to be little or no difference between specimens from the headwaters of Bosworth Creek and from Bosworth Creek reservoir.

Fish (9) were collected from the Mackenzie River downstream of Norman Wells in August 1985. Livers and fish muscle were analyzed for light hydrocarbons by Esso's Production Research Laboratory and the Department of Fisheries and Oceans respectively.

Air Quality

An air quality monitoring system was established utilizing 8 remote sampling stations and a sophisticated NO_2, NO_x, H_2S, and SO_2 monitoring trailer. Results are reported separately in Section 4 (Air Quality Monitoring at Norman Wells).

Vegetation Analysis

False color infra-red aerial photographs were taken during summer 1984 at a scale of 1:5000 over a 32 km strip, 16 km upwind and downwind of Norman Wells.

Soils Analysis

Surface and subsurface composite soil samples were taken at eleven stations surrounding Norman Wells in summer 1984. Basic soil fertility, heavy metal levels, and sulfate concentrations were determined.

Noise Survey

Noise levels were surveyed around Esso facilities and at the edge of the lease nearest permanent residents. Noise levels were within acceptable limits.

Future Studies

These data serve to characterize environmental conditions in the area prior to oilfield expansion. Periodic resampling for selected monitoring parameters will be conducted as necessary.

Reports Available

Dawson, C. 1985. Analysis of Fish Tissues for Light Hydrocarbon Contamination. Internal Report. Analytical and Process Technology Section, Production Research Division, Esso Resources Canada Limited.

Lund, E. 1984. Analysis of Fish Tissues for Light Hydrocarbon Contamination. Internal Report. Analytical and Process Technology Section, Production Research Division, Esso Resources Canada Limited.

Sikstrom, C.B. 1986. Scientific Permit F-85/86-05: A report dated 86-03-06.

Sikstrom, C.B. 1985. Scientific Permit F-84/85-11: A report dated 85-06-05.

Further information regarding baseline environmental monitoring results for Norman Wells is available through the Esso Norman Wells office.

Contact

Mr. John Oxtoby
Esso Resources Canada Limited
Bag 5000
Norman Wells, N.W.T. X0E OVO
(403) 587-2561

Mr. Calvin Sikstrom
Esso Resources Canada Limited
237 - 4 Avenue S.W.
Calgary, Alberta T2P 0H6
(403) 237-3737

3. ISLAND MONITORING & MACKENZIE RIVER BREAKUP

Agency Responsible

Esso Resources Canada Limited

Start-up Date

Spring 1984

Objectives

1. to determine the effects of the production islands on the breakup process;
2. to confirm the stability and design adequacy of the production islands;
3. to determine maintenance requirements for the production islands and under-river pipeline systems.

Locations

Mackenzie River, between 10 km upstream and 10 km downstream of Norman Wells.

Results to Date

1. Breakup survey data for the years 1980, 81, 82, 83, and 84.
2. Geotechnical monitoring data for Dehcho Island which includes temperature and pore pressure measurements.
3. Bathymetric data showing bottom profiles and island pipeline locations in the river.

Conclusions/Recommendations

1. Breakup timing can be closely predicted.
2. Production islands have performed as expected and do not seriously affect the breakup process.
3. Production islands are stable, well designed facilities.

Future studies

1. Continued monitoring of breakup timing and Esso's predictions.
2. Periodic bathymetric surveys of the Norman Wells reach.

Reports available

Kamphuis, J.W. and J.R. Moir. 1983. Ice breakup and jamming observations along the Mackenzie River. Can. J. Civil Engineering. 10(1):78-91.

Kemp, T.S. 1982. Mackenzie River Norman Wells 1982 breakup. Esso Resources Canada Limited, Research Department. IPRT.ME.82.30

Kemp, T.S. 1983. Mackenzie River and Norman Wells breakup 1983. ERCL.RS.85.11

Kemp, T.S. 1985. Mackenzie River at Norman Wells breakup 1985. ERCL.RS.85.23

Kemp, T.S. and M. Kuyper. 1985. Mackenzie River and Norman Wells breakup 1984. ERCL.RS.85.11

Moir, J.R. 1979. A review of the design and impact on the river of artificial islands in the Mackenzie River at Norman Wells. Esso Resources Canada Limited, Research Department, IPRT.2ME.7a.

Northwest Hydraulic Consultants Ltd. 1979. Regime of Mackenzie River at Norman Wells in relation to artificial island scheme. Prepared for: Esso Resources Canada Limited. 32 pp.

Northwest Hydraulic Consultants Ltd. 1981. Hydraulic model study Norman Wells production island. Prepared for: Esso Resources Canada Limited. 17pp.

Fennell, D.J. and J.A. Oxtoby. 1987. Mackenzie River breakup at Norman Wells, 1986. ERCL.PR.87.19

Oxtoby, J.A. 1987. Mackenzie River Breakup at Norman Wells, 1987. ERCL.PR.87.19

Riard, G. 1985. Analysis of a Mackenzie river ice jam. MSc. Thesis, University of Alberta.

Stagg, P.G. 1983. Ice design review of Esso Resources' artificial islands in the Mackenzie River at Norman Wells. Esso Resources Canada Limited, Research Department. IPRT.ME.83.01

Detailed breakup and island monitoring reports are submitted to the N.W.T. Water Board annually to satisfy island monitoring requirements. Bathymetric data may be viewed at the Esso Norman Wells office.

Contact

Mr. John Oxtoby
Esso Resources Canada Limited
Bag 5000
Norman Wells, N.W.T. X0E OVO
(403) 587-2561

Mr. Calvin Sikstrom
Esso Resources Canada Limited
237 - 4 Avenue S.W.
Calgary, Alberta T2P 0H6
(403) 237-3737

4. AIR QUALITY MONITORING AT NORMAN WELLS

Agencies Responsible

Environmental Protection (Department of the Environment)
Esso Resources Canada Limited

Start-Up Date

1981.

Objectives

In response to an EARP Panel recommendation, Esso Resources Canada Limited and Environmental Protection commenced a joint air sampling program in the summer of 1981. The objective of the program was to determine the effect of the expansion project on selected ambient air quality parameters before, during, and after construction.

Description of sampling program: particulates and lead

As part of the joint program, Environmental Protection:

1. provided two high volume air samplers and all necessary accessories for their operation and maintenance;
2. installed the equipment at two locations;
3. trained Esso Resources staff in the operation, calibration, and maintenance of the equipment; and
4. analyzed the samples and prepared a report.

Esso Resources Canada Limited:

1. committed staff to the project;

2. operated and maintained all equipment; and
3. collected and sent samples to Environmental Protection.

Standard high volume air samplers were used for the collection of suspended particulates and lead. Large volumes were drawn through a fabric filter, capturing particulates in the 5 to 100 micron range. Samples were collected according to the National Air Pollution Surveillance (NAPS) program sampling schedule, which called for a sample to be taken from midnight to midnight, every six days.

Description of sampling program: sulphur and nitrogen compounds

Esso's program for these parameters was divided into two sub-programs:

1. Exposure station monitoring for total sulphation and hydrogen sulphide; and
2. Continuous ambient monitoring of wind speed and direction, NO_x, NO_2, NO, H_2S, and SO_2.

Exposure station monitoring began in July 1984 and continued until April 1986 at eight stations which were located to receive maximum exposure to Esso facility emissions.

Continuous ambient monitoring occurred from July 18 to September 6, 1984, and from July 10 to September 10, 1985, and was conducted by Esso and the Western Research Division of Bow Valley Resource Services Ltd. An air monitoring trailer was set up near the Central Processing Facility and operated continuously for a three month period each summer. The scheduling of these two monitoring periods resulted in data collection before and after Central Processing Facility start-up. Sulphur dioxide and hydrogen sulphide concentrations were recorded using Monitor Labs 8850 analyzers. Nitrogen dioxide concentrations were recorded using a Monitor Labs 8840 analyzer. Wind speed and direction were recorded by an RM Young

wind instrument.

Locations

The high volume sampling equipment was installed on the roof of the airport building at the east end, and on the roof of the Esso Resources Canada Limited production garage at the west end, of Norman Wells. The latter was taken out of service in 1985.

Exposure station locations and prevailing wind directions as well as the approximate locations of the air quality monitoring trailer in 1984 and 1985 are shown in Figure 4.1. The 20 year Canadian wind normals for Norman Wells were obtained from Environment Canada's meteorological station at Norman Wells, and used as one of the specifications for locating the air monitoring trailer.

Results to Date

1. Air Quality Objectives

Since there are no territorial air quality standards for the N.W.T., federal standards were used where available. Federal standards have not been set for lead, NO_x, and H_2S. For these three parameters, air quality objectives from British Columbia, Alberta, and Saskatchewan were obtained, and the most rigorous were used to produce Table 4.1 - Ambient Air Quality Objectives.

2. Total Suspended Particulates

Mean concentrations of ambient particulates for the airport station are shown in Table 4.2 and raw data are presented in Tables 4.3, 4.4, and 4.5. Insufficient data existed to provide even an estimate of the annual values for 1982 and 1985 at the airport station.

Therefore, the annual results for these years have been reported for information purposes only and should not be considered to be true mean values. Summer values were arbitrarily defined as those occurring between June 1st and September 30th.

The results are summarized as follows:

a. Average summer concentrations were between 6 and 11 times higher than average winter concentrations.
b. Average concentrations were highest during the peak of quarrying activity in 1982 and although they have been steadily declining since 1982, the values remained high until the end of construction.
c. During the summer, concentrations exceeded the Environment Canada acceptable 24 hour limit of 120 ug/m^3, 75% of the time in 1982, down to 13% of the time in 1985.

3. Lead

From the Third Annual Report, the results for lead indicated no major concerns, and therefore lead concentrations were not considered in great detail for this report. As a point of information, the maximum lead concentration in 1985 was 0.10 ug/m^3 and 15 of the 22 samples analyzed contained no lead (ie. less that 0.005 ug/m^3). Raw data for lead concentrations from 1981 to 1985 are presented in Tables 4.3, 4.4, and 4.5.

4. H_2S, NO, NO_2, NO_x, and SO_2

Exposure station monitoring results for the period August 1984 through April 1986 are shown in Figure 4.2 for hydrogen sulphide and Figure 4.3 for total sulphation as sulphate equivalents. All measured parameters were at least one order of magnitude lower than Alberta standards. Measured parameters (NO_2 and SO_2) were also

lower than those predicted by Alberta Environment computer programs for plume dispersion calculations which were applied to major emission sources in the area. Measurable amounts were attributable to local sources. The H_2S readings were attributed to the Battery 3 flare pit and the now abandoned refinery heavy fuel oil flare. All observed NO_x readings were attributed to vehicular traffic, except on the infrequent occasions when northerly winds caused the measurement of emissions from the four-cylinder diesel generator used to power the air quality monitoring trailer.

Detailed results of the ambient air quality monitoring conducted in 1984 and 1985 are available for viewing at the Esso Norman Wells production office. A summary of these results is provided in Tables 4.6, 4.7, 4.8, 4.9, and 4.10. No levels which would exceed the objectives in Table 4.1 were encountered. All measured levels were an order of magnitude below common standards.

Conclusions

1. Start-up and operation of the new Central Processing Facility at Norman Wells had only minor localized effects on ambient levels of hydrogen sulphide, nitrogen oxides, and sulphur oxides in the Norman Wells area.

2. Measured levels of common air pollution parameters were too low and infrequent for emissions to be attributed to any particular source.

3. After the quarrying activity ceased, the major contributor to particulate concentrations in Norman Wells seemed to be vehicular traffic on the gravel roads. This would explain the much lower values in winter when the road surfaces are frozen.

4. Construction was essentially complete by the end of 1984, and this is reflected in the lower particulate concentrations which occurred in 1985. Particulate generation would appear to be a concern only during quarrying or trucking activities on gravel roads.

Recommendations

1. Air quality monitoring programs for future hydrocarbon developments should be realistically designed with appropriate consideration of industry activities in relation to their possible impact on communities or sensitive environmental areas.

2. The application of Alberta environmental standards and protocols should be considered for determining acceptable air quality methods and standardizing reporting requirements in the Northwest Territories.

3. To reduce the effects of construction activity on ambient air quality, appropriate dust suppression measures should be implemented.

Future Studies

Since no air quality concerns were identified, high volume sampling, exposure stations, and ambient air quality monitoring have been discontinued.

Reports Available

Environment Canada. November 1976. Criteria for National Air Quality Objectives, Federal-Provincial Committee on Air Pollution.

Environment Canada. December 1986. Norman Wells NAPS Station Results for 1985.

Esso Resources Canada Limited. July 1985, November 1985. Summary Reports on the Exposure Station Monitoring Program submitted to Environmental Protection Service. Detailed results of the ambient air quality monitoring program are available for viewing at Esso's Norman Wells Production Office.

Federal Environmental Assessment Review Office. January 1981. Report of the Environmental Assessment Panel on the Norman Wells Oilfield Development and Pipeline Project.

Touzin, M. 1984. Air Quality Monitoring at Norman Wells July 18 to September 1984. Unpublished report. Production Research Department, Esso Resources Canada Limited.

Contact

Mr. Ed Collins, P. Eng.
Environmental Protection
Conservation and Protection
Environment Canada
N.W.T. District Office
Box 370
Yellowknife, N.W.T. X1A 2N3
(403) 873-3456

Mr. John Oxtoby
Esso Resources Canada Limited
Bag 5000
Norman Wells, N.W.T. XOE OVO
(403) 587-2561

Mr. Calvin Sikstrom
Esso Resources Canada Limited
237 - 4th Avenue, S.W.
Calgary, Alberta T2P 0H6
(403) 237-3737

Figure 4.1 Locations of Norman Wells air quality monitoring exposure stations (1-8)

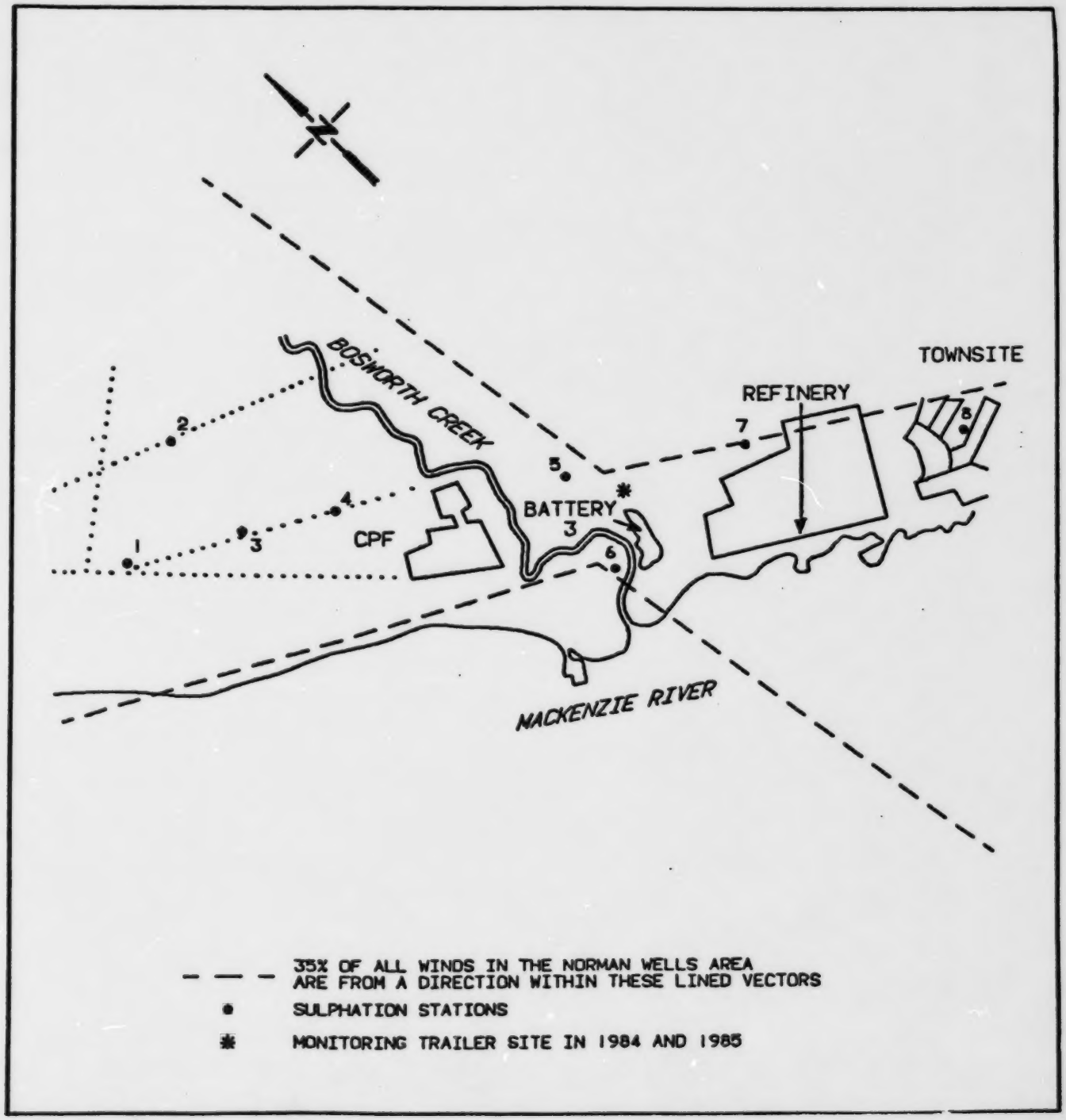


Figure 4.2 Hydrogen sulfide (mg SO_3/day/100 cm^2) at Norman Wells N.W.T. for eight exposure stations during the period of August 1984 to March 1986

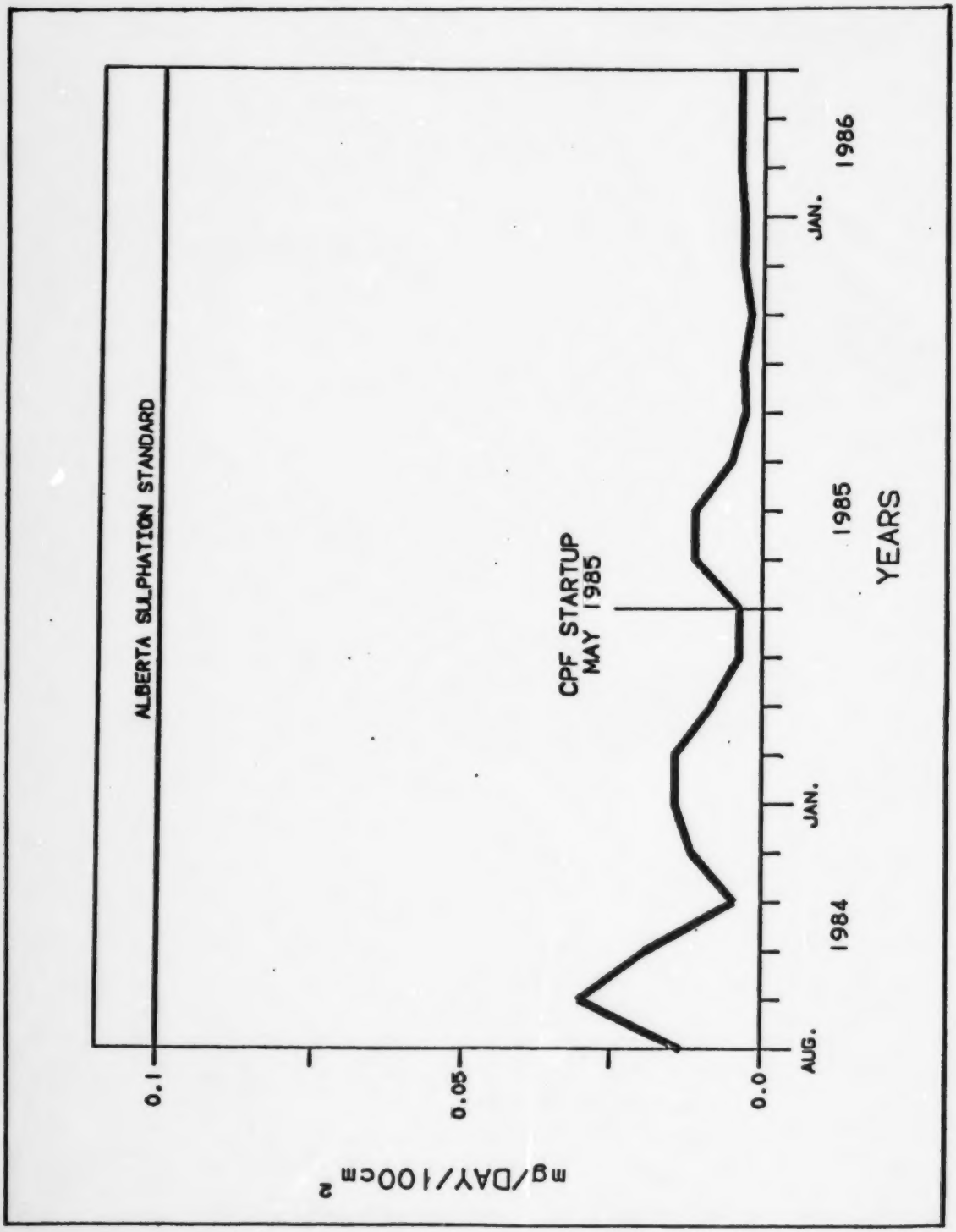


Figure 4.3 Total sulphation (mg SO_3/day/100 cm^2) at Norman Wells N.W.T. for eight exposure stations during the period of August 1984 to March 1986

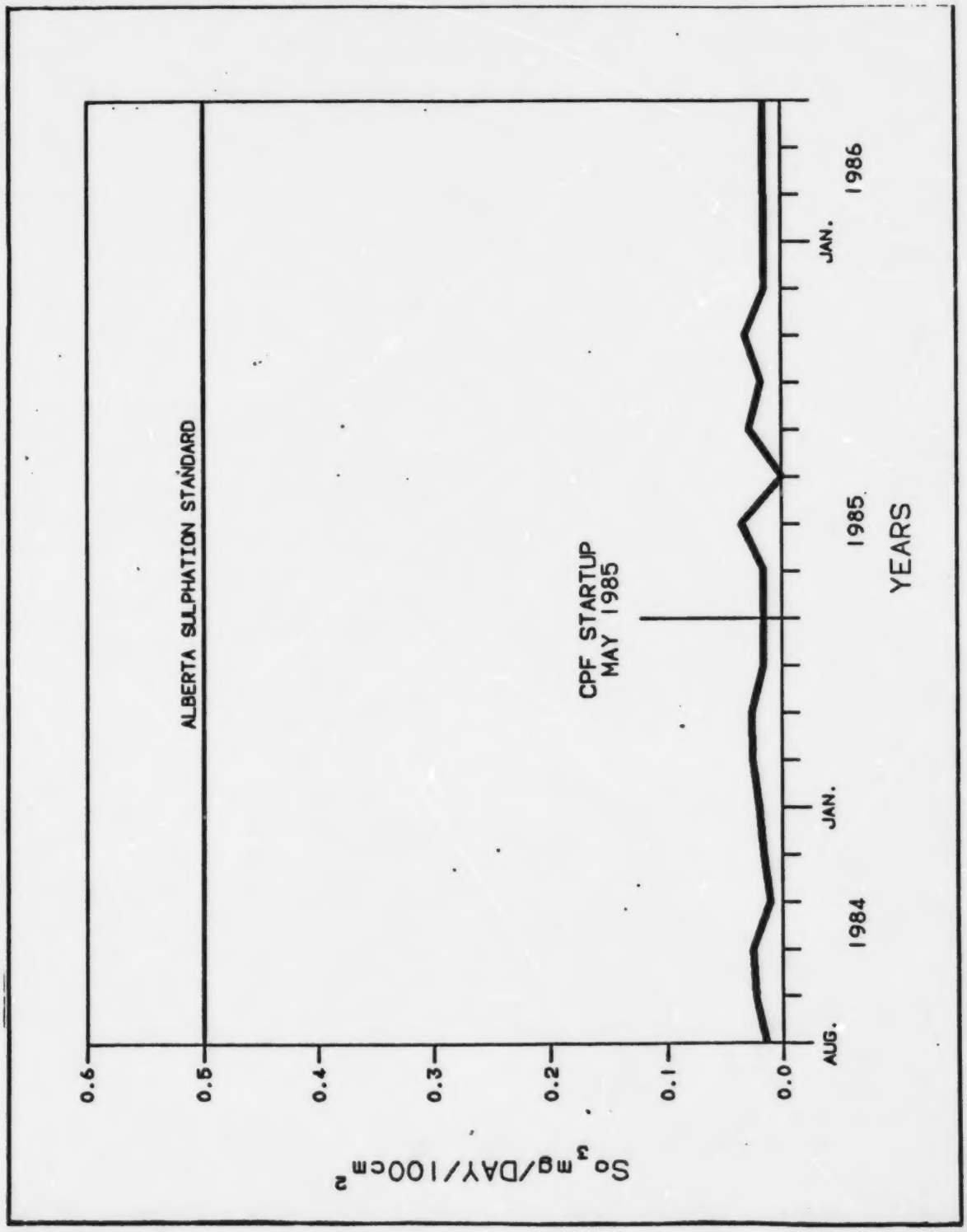


Table 4.1 Ambient air quality objectives

Parameters	Units	Jurisdiction	Time Period	Concentrations Maximum Desirable	Concentrations Maximum Acceptable
TSP	ug/m^3	Federal	Annual mean	60	70
			Max. 24 hour		120
Pb	ug/m^3	B.C.	Annual mean		2
			Max. 24 hour		4
NO_2	ug/m^3	Federal	Annual mean	60	100
			Max. 24 hour		120
NO_x (as NO_2)	ug/m^3	Alberta	Annual mean		60
			Max. 24 hour		210
H_2S	ug/m^3	B.C.	Max. 24 hour		4
			Max. 1 hour		7.5
H_2S	$mgSO_3/100cm^2$	Alberta	Max. 24 hour		0.1
SO_2	ug/m^3	Federal	Annual mean	30	60
			Max. 24 hour	150	300
			Max. 1 hour	450	900
TOTAL SULPHATION	$mgSO_3/100cm^2$	Alberta	Max. 24 hour		0.5

Table 4.2 Total suspended particulate data for the airport station, Norman Wells, NWT (all concentrations in ug/m³)

YEAR	1981	1982	1983	1984	1985
WINTER					
No. of samples	9	3	11	14	6
Low	5	5	9	5	47
High	20	74	57	94	147
Average	12	*	18	16	*
% above 120	0	*	0	0	*
SUMMER					
No. of samples	17	16	9	13	16
Low	20	19	19	8	19
High	295	295	224	244	196
Average	129	172	126	101	65
% above 120	41	75	56	38	13
ANNUAL					
No. of samples	26	19	20	27	22
Average	71	*	67	54	*
% above 120	27	*	25	19	*

* Insufficient Data

Table 4.3 High volume sampler results for the airport station, Norman Wells, NWT

Date	Particulates ug/m³	Lead ug/m³	Date	Particulates ug/m³	Lead ug/m³
1981			1982		
June 15	87	0.04	Jan 5	13	0.08
21	63	0.05			
27	39	0.06	Apr 29	74	0.11
			June 29	260	0.09
July 2	20	<0.03	July 4	194	0.06
9	57	0.05	10	68	0.06
15	177	0.07	16	158	0.05
21	33	<0.03	22	250	0.08
27	52	<0.03	28	192	0.10
Aug 2	148	<0.03	Aug 3	232	0.06
8	295	0.13	9	295	0.08
14	125	0.07	15	287	0.09
20	141	0.08	21	49	0.06
26	219	0.09	28	249	0.05
Sept 1	21	0.04	Sept 2	19	0.09
7	76	0.04	8	151	0.05
19	158	<0.03	14	196	0.13
25	28	<0.03	21	189	0.08
			26	50	0.05
Oct 1	---	<0.03	Oct 2	5	0.03
7	8	<0.03			
13	17	0.06			
19	20	<0.03			
25	14	0.05			
31	12	<0.03			
Nov 7	13	0.04			
12	8	0.04			
18	5	<0.03			
Dec 6	7	<0.03			
12	---	0.06			
19	---	<0.03			
24	---	<0.03			
30	---	<0.03			

Table 4.4 High volume sampler results for the airport station, Norman Wells, NWT

Date	Particulates ug/m³	Lead ug/m³	Date	Particulates ug/m³	Lead ug/m³
1983			1984		
			Jan 17	94	0.15
			Feb 18	9	0.14
			24	33	0.15
June 5	66	0.00	June 23	141	0.10
17	94	0.05			
			July 5	164	0.10
23	153	0.02	11	8	0.10
29	224	0.06	17	33	0.10
			23	54	0.00
Aug 10	19	0.02	Aug 4	54	0.10
16	54	0.06	10	69	0.00
28	169	0.05	16	33	0.01
			22	186	0.01
Sept 9	179	0.07	Sept 9	8	0.00
15	174	0.04	15	239	0.00
			21	75	0.10
			27	244	0.20
Oct 9	11	0.03	Oct 9	7	0.10
15	57	0.03	15	8	0.10
21	29	0.08	21	5	0.10
27	12	0.17			
Nov 2	9	0.06	Nov 14	8	0.20
8	13	0.00	20	7	0.00
14	11	0.15	26	7	0.20
20	10	0.02			
Dec 8	20	0.40	Dec 2	5	0.10
20	11	0.32	8	9	0.10
26	14	0.01	14	9	0.20
			20	11	0.40
			26	9	0.30

Table 4.5 High volume sampler results for the airport station, Norman Wells, NWT

Date		Particulates ug/m³	Lead ug/m³
1985			
April	1	47	0.10
May	1	60	0.10
	7	48	0.00
	13	115	0.10
	19	147	0.00
	25	120	0.00
June	6	51	0.00
	18	64	0.00
	24	184	0.00
	30	94	0.00
July	6	27	0.00
	12	70	0.00
	18	60	0.00
	30	38	0.00
Aug	11	33	0.00
	17	19	0.00
	23	24	0.10
	29	196	0.10
Sept	4	28	0.10
	10	28	0.00
	22	55	0.00
	28	76	0.10

Table 4.6 H_2S monthly averages and frequency distributions of one - hour readings at Norman Wells

July 18 to September 6, 1984 and July 10 to September 10, 1985

Date	Number of Readings	% Readings in concentration range (ppb H_2S)				Monthly Average ppb
		0 - 3	4 - 10	11 - 50	>50	
July 1984	319	99.4	0.6	0.0	0.0	0.0
Aug 1984	701	99.4	0.6	0.0	0.0	0.0
Sept 1984	122	100.0	0.0	0.0	0.0	0.0
					Annual Average	0.0
July 1985	28	100.0	0.0	0.0	0.0	0.1
Aug 1985	54	100.0	0.0	0.0	0.0	0.1
Sept 1985	23	100.0	0.0	0.0	0.0	0.1
					Annual Average	0.1

Table 4.7 SO_2 monthly averages and frequency distributions of one - hour readings at Norman Wells

July 18 to September 6, 1984 and July 10 to September 10, 1985

Date	Number of Readings	% Readings in concentration range (ppm SO_2)					SO_2 ppm Monthly Average
		.00 -.02	.03 -.06	.07 -.17	.18 -.34	>.34	
July 1984	339	100.0	0.0	0.0	0.0	0.0	0.0
Aug 1984	727	100.0	0.0	0.0	0.0	0.0	0.0
Sept 1984	130	100.0	0.0	0.0	0.0	0.0	0.0
					Annual Average	0.0	
July 1985	1	100.0	0.0	0.0	0.0	0.0	0.0
Aug 1985	1	100.0	0.0	0.0	0.0	0.0	0.0
Sept 1985	1	100.0	0.0	0.0	0.0	0.0	0.0
					Annual Average	0.0	

Table 4.8 NO_2 monthly averages and frequency distributions of one - hour readings at Norman Wells

July 18 to September 6, 1984 and July 10 to September 10, 1985

Date	Number of Readings	% Readings in concentration range (ppm NO_2)			NO_2 ppm Monthly Average
		.00 -.11	.12 -.21	>.21	
July 1984	357	100.0	0.0	0.0	.001
Aug 1984	739	100.0	0.0	0.0	.001
Sept 1984	129	100.0	0.0	0.0	.002
				Annual Average	.001
July 1985	41	100.0	0.0	0.0	.001
Aug 1985	23	100.0	0.0	0.0	.000
Sept 1985	0	100.0	0.0	0.0	.000
				Annual Average	.000

Table 4.9 NO monthly averages and frequency distributions of one - hour readings at Norman Wells

July 18 to September 6, 1984

Date	Number of Readings	% Readings in concentration range (ppm NO)			Monthly Average
		<.11	.12 - .21	>.21	
July 1984	357	100.0	0.0	0.0	.002
Aug 1984	739	100.0	0.0	0.0	.001
Sept 1984	129	100.0	0.0	0.0	.002
				Annual Average	.002

Table 4.10 NO_x monthly averages and frequency distributions of one - hour readings at Norman Wells

July 18 to September 6, 1984

Date	Number of Readings	% Readings in concentration range (ppm NO_x)			Monthly Average
		<.11	.12 - .21	>.21	
July 1984	357	100.0	0.0	0.0	.003
Aug 1984	738	100.0	0.0	0.0	.002
Sept 1984	129	100.0	0.0	0.0	.004
				Annual Average	.003

5. PERMAFROST AND TERRAIN RESEARCH AND MONITORING

Agencies Responsible

Geological Survey of Canada, Department of Energy, Mines & Resources,
Department of Indian Affairs and Northern Development,
National Research Council of Canada,
Agriculture Canada,
Interprovincial Pipe Line (NW) Ltd.

Start-Up Date

1983.

Objectives

1. to determine and quantify the impacts of pipeline construction, operation, maintenance and abandonment on permafrost and northern terrain;

2. to evaluate the recovery processes and the effectiveness of short and long term mitigative measures;

3. to compare actual and predicted impacts in order to improve on planning, design, impact management and mitigation on northern pipelines; and,

4. to recommend improved environmental practices for future northern pipelines.

Locations

See descriptions given for specific projects.

Program Background

The Norman Wells Pipeline provides an important opportunity to examine the impacts of the first completely buried oil pipeline in the discontinuous permafrost zone of northern Canada. The small diameter (323 mm) pipeline with innovative designs and features has been in operation since April 1985. It is viewed as a pilot project from which important lessons may be learned for future oil and gas developments.

The Departments of Indian and Northern Affairs (INAC) and Energy, Mines and Resources (EMR) initiated preliminary plans in 1983 for a cooperative permafrost and terrain research and monitoring program with Interprovincial Pipe Line (NW) Ltd. (IPL) under the "Environmental Agreement" signed between IPL and the Minister of Indian and Northern Affairs in September 1982. The current program consists of the following four integrated projects:

A. Impact of the Norman Wells pipeline project on permafrost, terrain and terrain stability - Permafrost Research Section, Geological Survey (EMR) (formerly Earth Physics Branch) (See Section 5.A);

B. Terrain performance research and monitoring along the Norman Wells to Zama oil pipeline - Terrain Sciences Division, Geological Survey (EMR) (See Section 5.B);

C. Evaluation of wood chip insulation on selected thaw sensitive slopes along the Norman Wells to Zama Pipeline - Institute for Research in Construction, National Research Council (NRC) (See Section 5.C); and,

D. Norman Wells Pipeline soil temperature study - Land Resources Research Center, Agriculture Canada (Ag.Can.) (See Section 5.D).

The Permafrost and Terrain program focuses on the effects of construction, operation and maintenance of the pipeline on the surrounding ground temperature, moisture, stability and related surface conditions. The major emphasis of the research and monitoring involves:

1. thermal and associated data collection at selected sites, and
2. general observations of conditions along the right-of-way (Km. 0-818). The program is expected to continue for five to ten years or until conditions stabilize.

Funding (1983-1988) comes primarily from the Northern Oil and Gas Action Program (NOGAP) and the Northern Affairs Program (NWT Region) of Indian and Northern Affairs Canada. Additional funding and contributions are provided from the Program on Energy Research and Development (PERD), Energy, Mines and Resources, NRC, and Agriculture Canada. We wish to express our appreciation to all contributors to the program (IPL, INAC, EMR, NRC, Ag.Can) and especially to Land Resources staff F. Adlem and L. Edwardson.

Contact

Dr. Kaye MacInnes, Program Coordinator
Land Resources Division
Department of Indian Affairs and Northern Development
Box 1500
Yellowknife. N.W.T. X1A 2R3
(403) 920-8152 Telex: 034-45505

5.A. THERMAL REGIME AND TERRAIN STABILITY

Agencies Responsible

Permafrost Research Section (formerly part of Earth Physics Branch), Geological Survey of Canada,
Department of Energy, Mines and Resources,
in cooperation with: Department of Indian Affairs and Northern Development, National Research Council of Canada, Agriculture Canada, and Interprovincial Pipe Line (NW) Ltd.

Start-Up Date

1983.

Objectives

1. to monitor both short and long term changes in the active layer, in the permafrost and in terrain stability of the alignment area in relation to pipeline development and natural climatic change at selected study sites;

2. to assess the changes to the thermal and physical condition of terrain caused by pipeline-related activity, including right-of-way clearance, pipeline installation, operation and maintenance;

3. to compare observed terrain conditions with those predicted during the pipeline design process, including thaw depth, thaw settlement and frost heave of the surface;

4. to evaluate the effectiveness of mitigation and restoration procedures and recovery at the study sites, including thermal

performance of the pipe, wood chip insulation of slopes, drainage control and revegetation; and

5. to identify practical improvements which might be made in the planning, construction, operation, monitoring and abandonment of future northern pipelines, with special reference to the assessment of environmental impacts including route selection, thermal design, ground surface protection, land stabilization and restoration.

Locations

See Table 5.1 and Figure 5.1

Results to Date

1983-1985 Observations and Results

Six monitoring sites were established during the 1983/1984 construction season and seven sites during the 1984/85 season. These 13 locations (shown in Figure 5.1 and described in Table 5.1) were selected to:

1. investigate the terrain response to particular pipeline design features and mitigative measures, including areas of thaw sensitive terrain, frozen/unfrozen interfaces and a wood chip insulated slope; and,

2. to represent the soil and ground ice conditions along the route.

Each monitoring site generally consists of one to three instrumented cross-sections, called thermal fences and designated A, B or C. An example of the layout of a thermal fence, shown in Figure 5.2,

illustrates the depth and distribution of boreholes instrumented with temperature cables. Two 5 m cables close to the pipe examine the immediate effect of pipeline installation and operation. Two 20 m cables (on and off ROW) investigate the deeper thermal characteristics and enable a comparison of the thermal regime of the disturbed ROW and surrounding terrain. A string of five thermistor sensors attached to the pipe provide a reference value for pipe-induced thermal disturbance.

Temperature cable installation at the 1984 sites began in June 1984 and was completed in September 1984; at the 1985 sites, cable installation was completed by the end of March 1985. The basic long term (10 years) monitoring program includes monthly site visits emphasizing the acquisition of thermal data.

In addition to the thermal information, geophysical surveys and topographic surveys were also conducted. Ground probing radar surveys were conducted in December 1983, June 1984, September 1984 and May 1985. Time domain reflectometry (TDR) rod installation began in September 1984 and was completed in October 1984. TDR surveys were conducted in September 1984, November 1984, May 1985 and June 1985. Ground surface elevation surveys were obtained in June 1984, August 1984, May 1985 and September 1985.

Temperature cables at remote and selected sites (Canyon Creek 2A, Great Bear 3A, Table Mountain 7A and 7B) were equipped with automatic data systems in October 1985. In collaboration with the Atmospheric Environment Service (Environment Canada), a micrometeorological station was set up at the Canyon Creek 2A site in March 1985.

The data collected during the 1983-1985 period yielded information on the following:

1. thermal regime on and off the pipeline right-of-way (ROW), in particular the effects of snow clearance during construction, pipeline trenching, water ponding, woodchip insulation, snow distribution and differential active layer development;

2. distribution and redistribution of water both on and off the ROW, within and below the active layer, and the associated changes in soil electrical characteristics;

3. variation of the active layer both with time and along continuous profiles across the ROW; and

4. terrain heave and settlement at the monitoring sites.

Late 1985 and 1986 Observations and Results

1. Data collection

Monthly site visits to collect ground temperature data continued throughout the year for all sites (as per schedule in Table 5.2) except the remote locations of Table Mountain, Redknife Hills and Petitot River (north and south). In June, ground probing radar surveys were conducted at the Great Bear monitoring sites. Downhole electrical conductivity measurements were also carried out in June using the geophysical holes at Pump station 1, Canyon Creek (A, B and C) and Great Bear (A and B). TDR measurements were taken at all sites both in May and in October. In September, all fences in the N.W.T. were resurveyed.

2. New instrumentation

In March 1986, a drilling program was undertaken at the Table Mountain sites to establish new off-ROW reference holes at each of

the three fences. Three new holes were drilled in an attempt to achieve less off-ROW ground surface disturbance than had occurred during the 1985 drilling. The new hole at fence A was deepened to 93 m to provide a reference for long term climatic changes in this area of the Mackenzie Valley.

In August, shallow 1.5 m soil temperature probes were installed at 13 fences, both on and off the right-of-way, as part of a new project undertaken in cooperation with Agriculture Canada (Tables 5.3, 5.4). Permanent snow depth stakes were installed in August and September. In September, additional instrumentation was installed on the woodchip slope fence at Canyon Creek B as part of a new project, in cooperation with the National Research Council, to evaluate wood chip insulation.

In the fall of 1986, four IPL thaw settlement sites were instrumented with pairs of 10 m temperature cables. Two of these sites overlap with existing fences (km 272.0 and 608) and two are at new locations (km 135.1 and 469.7). An additional site (km 95.1) was instrumented with one cable. The instrumentation was undertaken in cooperation with IPL in conjunction with their drilling program at thaw settlement monitoring sites.

In October, a fifth automatic data acquisition system was installed at Petitot River North B to ensure that a continuous annual record was obtained in one of the remote peat plateau sites in northern Alberta. This fence now joins Table Mountain A and B, Great Bear A and Canyon Creek A on the list of sites with an automatic system. These loggers are connected to the ground temperature cables (and to the soil probes at three fences as well) but not to the pipe temperature sensors.

3. IPL remedial work at instrumented fences

Winter remedial work was carried out by IPL in February and March 1986 near several instrumented fences. Additions to erosion control berms were made at Canyon Creek C and new select backfill was added to the trenches at Manner's Creek C and Moraine South. In organic areas, organic surface material adjacent to the trench was bladed into and over the trench during March 1985 and late summer 1985.

4. Brief Climatic Perspective
(winter 85/86 based on AES records at Norman Wells and Fort Simpson)

Early snowfall (October-November 1985) was higher than in the previous winter, while later snowfalls (January and February) were lower. Winter mean monthly temperatures were colder than normal in October, November, January, February and April, and warmer than normal in December and March. For summer 1986 conditions, see summary in Section 5.B (Terrain Performance).

5. Results

Thermal changes resulting from right of way widening and clearance, tree removal and ground surface grading, pipeline construction and trenching were apparent. A comparison of observations to the early and general thermal, active layer, and thaw settlement predictions of the Environmental Impact Statement and National Energy Board applications was also undertaken.

Highlights of analyses and observations through to October 1986 are as follows:

Pipeline Temperatures

A comparison of pipe temperatures and ground temperatures at a depth of 1 m on the ROW (at all EMR/INAC fences instrumented with pipe temperature sensors) were undertaken in order to determine whether the pipeline was behaving as an ambient temperature line (i.e. to examine the prediction that pipe temperatures would closely follow the temperatures of the surrounding soil).

An examination of the pipe temperature data at individual fences or small groups of fences showed that:

a. Data from Canyon Creek A, B, and C:
   Prior to oil filling the line, temperatures of the pipe and of the surrounding soil at each fence were in close agreement (within 1 degree) and pipe temperatures were distinct from one fence to the next. After oil flow, pipe temperatures at each fence no longer closely followed the ambient soil temperatures (differences of up to 4 degrees). Pipe temperatures, however, were similar at each fence.

b. Since oil flow, all fences from km 477 south to km 818, whether permafrost or non-permafrost, clearly have shown a mean annual pipe temperature above 0°C. In fact, at many of these fences (9, 10A, 10B, 11 12A, 12B; and likely 5A, 5B, and 6, although no mid-winter data were collected at the last three fences) pipe temperatures were positive throughout the last year.

c. Pipe temperatures in the northern section from site 84-1 to 85-7C (km 272), where permafrost underlies 75% of the terrain, appeared to be averaging around 0°C on an annual basis since oil flow.

d. Since oil flow, the pipe temperatures have consistently risen by

2 to 3°C from fence 9 to fence 10A (Mackenzie Highway South), a distance of only 5 km. Pump Station 3 is located between these two sites. The highest pipe temperatures of all the sites have usually been recorded at the Mackenzie Highway South fences (temperatures of up to 10°C were recorded in the summer of 1986).

Terrain Stability

a. Surface topography changes across the ROW (not only at the trench) have become apparent at several southern permafrost sites. A wide swath of relative settlement has formed on either side of the trench, covering a total width of approximately 10 m and often skewed to the spoil side (fences 6, 5A, 5B, 13A, 13B, 12B, 10B, 8C, and 8B). These changes have likely resulted from differential active layer deepening and thaw subsidence across the ROW; in addition, at some organic sites, this area was bladed for trench re-roaching.

b. Uneven (sometimes undulating) surfaces and tension cracks have appeared on several woodchip slopes; these suggest either differential settlement in the chips or in the soil beneath. Differential snow melt observed on many woodchip slopes in October 1986 suggests differential heating (decomposition) in the pile.

Changes in Permafrost Depth

The thin permafrost (less than 4 m) originally noted at fence 10B (new clearing) and fence 11 (recent helipad clearing) has now disappeared on the right-of-way.

November 1986 to October 1987 Observations and Results

1. Data collection

Monthly site visits to collect ground temperature data continued for all sites (see Table 5.2 for schedule of field work). Time domain reflectometry (TDR) measurements were taken at all sites both in May 87 and October 87. In August, topographic surveys were undertaken at all thermal fence locations with the exception of 84-2A, 84-2C, 85-9 and 85-11.

In October 1987, a sixth automatic data acquisition system (Seadata) was installed at Table Mountain 85-7C and connected to ground temperature cables T1 through T4. Seadata loggers are currently set for three readings per day. A defective logger at site 84-5B was replaced. A prototype interface unit, allowing manual readings on the cables during regular field trips without disconnecting from the Seadata loggers, has been designed and installation is planned for spring 1988. New loggers have also been installed to increase the frequency of pipe temperature readings at select sites. (See section 5.D)

2. New Instrumentation

In March 1987, a deep drilling program was undertaken at two locations in the Norman Wells area in order to examine the ground temperature profiles for evidence of climate change. The holes will provide reference sites for long term study of climate change and ground temperature relationships. The first site was at valley level (elevation 120 m) near site 84-2A, Canyon Creek, while the second was situated on top of Kee Scarp (elevation 365 m), about 5 km north of Norman Wells. The sites were selected to determine whether there is a relationship between observations and elevation and whether this

might in turn be related to the temperature inversions commonly found along the valley in winter. Two holes were drilled (45 m and 129 m) and instrumented to full depth with multithermistor temperature cables at each site by September 1987.

In May 1987, soil displacement gauges (a series of ring magnets buried sequentially around teflon-covered access tubes to depths of 1.5 m) were installed both on and off ROW at two monitoring fences for experimental examination of the dynamics of near-surface materials. Measurements obtained should enable long term monitoring of relative displacements and indicate the amount of frost heave and thaw settlement. Baseline measurements were taken in October. Further readings are scheduled for May and October 1988.

3. Analyses

The first phase of laboratory investigations of the frozen cores collected from the geophysical holes drilled at the 1985 monitoring sites was completed in March 1987. This phase, undertaken in the EMR cold room at -10°C (keeping the samples undisturbed), involved a general visual description of lithology and ground ice, a photographic and video record, estimates of total density, a general survey of the thermal conductivity (at -10°C) using the needle probe technique and determination of the apparent dielectric constant by conventional intrusive TDR (time domain reflectometry) methods. Phase II of the core analyses, now underway, involves a detailed study of the physical and thermal properties and their temperature dependency, and emphasizes samples from sites 85-7B and 85-12B as well as selected samples from major soil units. Results from this research will be useful in determining the freezing point depression of the soils, in predicting thaw depths and thaw settlement at the thermal fences, and in numerical simulations of the thermal regime. Both phases of the research have been carried out under contracts to

Carleton University.

Mathematical curve fitting to the approximately monthly ground temperature and pipe temperature data collected at the monitoring sites has been undertaken (via contract) in order to interpolate between measured values. Weekly interpolated values are then used to obtain running mean annual temperatures (52 week running means). The running means can then be used to assess and compare the thermal regime adjacent to the pipe, on the ROW and off-ROW. To date, the analysis has been performed on the data collected through to the end of March 1987. Calculations including the data collected through to the end of October 1987 will take place this winter (1987/88).

Time domain reflectometry (TDR) field data will also be examined, via contract, to determine the temporal and lateral variations in soil moisture regime across each fence. Information on depth of thaw, the freezing point depression of the soils, and the presence/absence of a permanent thaw bulb/frost bulb around the pipe, will also be extracted.

4. Observations and results of analyses

Table 5.3 summarizes the mean annual pipe temperatures and the mean annual 1 m ground temperatures (on and off ROW) during the second year of operation (April 1986 - March 1987). The mean annuals were determined using the weekly interpolation values obtained by the method described in the previous section. Also provided in Table 5.3 is information on the range of settlement at the sites through to the end of the summer of 1986 based on a 20 x 20 m grid with a total of 100 points.

Figure 5.3 uses results of computer analyses of running mean annual temperatures to compare ground thermal regime (on and off ROW) with

pipe thermal regime for two thermal fences, 85-7B and 85-8A.

Ground temperatures from the deep climate holes show permafrost absent on Kee Scarp but present to depths of 25 m in the valley site. Temperature profiles suggest a recent one degree increase in surface temperature at Kee Scarp but not at Canyon Creek.

Conclusions/Recommendations

1. Trends in mean annual pipe and 1 m ground temperatures over the entire observation period (1984/1985 to March 1987) (preliminary results from computer analysis of thermal data)

In general, both the temperature of the pipe and the temperature of the ROW experienced a warming trend. The warming at most sites was greatest in the first year of operation, reflecting the atypical cooling of the ground due to snow removal during construction and pipeline installation. The rate of pipe and ground temperature increase is slowing down at most sites.

By contrast, an unambiguous warming trend in the off-ROW ground temperatures was observed at only about 25% of the sites (compared to 65% showing on-ROW warming and 75% showing pipe temperature warming). These off-ROW observations do not reflect the recent warming trend in mean annual air temperatures at Norman Wells and Fort Simpson. The warming trend observed on the ROW is thus likely a result of the pipeline construction rather than a response to the atmospheric trend.

2. Summary of observations during the second year of operation

Pipe temperatures:

Mean annual pipe temperatures were generally >0° during the second year of operation and ranged from -0.3 to +5°C. Values generally averaged 1.5 degrees warmer than mean annual ground temperatures on the ROW outside the trench area at a depth of 1 m. The ground thermal regime adjacent to the pipe in the trench is thus different from the ground thermal regime of the rest of the ROW, regardless of whether the site has been previously cleared or not, because the level of terrain disturbance is greater in the trench than elsewhere.

Ground thermal regime:

Mean annual ground temperatures on-ROW (depth 1 m) several metres from the trench ranged from -1.8 to +3.8° during the second year of pipeline operation. Mean annual 1 m ground temperatures off-ROW ranged from -2.6 to +2.6° during this period. Mean on-ROW temperatures generally averaged one degree warmer.

Active layers at the end of the 1986 thaw season at sites on level terrain ranged from <0.5 m to 2.5 m on-ROW; off-ROW they were generally <1 m. Active layers on-ROW generally increased over this observation period.

Surface settlement from topographic surveys:

Maximum recorded surface settlement to the end of the 1986 thaw season ranged from 60 to >100 cm in the trench area at 9 of 20 surveyed thermal fences. Some of the settlement in the trench area likely resulted from subsidence of the roach. On the ROW beyond the trench area, the maximum ranged from 50 to 80 cm at 6 of the 20

surveyed fences. Cumulative settlement to the end of the 1987 thaw season has yet to be determined from the 1987 topographic surveys.

Visual observations of surface settlement form part of IPL's geotechnical monitoring program. They have identified areas for detailed investigation where the possibility exists for thaw settlement greater than the design differential beneath the pipe over a short distance. Surface settlements over 60 cm in the trench area and over 50 cm elsewhere on the ROW, have been recorded at three thermal fences (84-1, 85-7B, and 85-12B). These are included in the detailed thaw settlement investigation.

3. Recommendations

A longer observation period is required in order to establish:

a. whether the general warming trend observed in the pipe temperatures and on the ROW is continuing;
b. whether the deceleration in the warming trend, where observed, represents the establishment of a new, higher equilibrium surface temperature.

Future Studies

The monitoring program should continue until the ground thermal regime (active layers, permafrost thickness, mean annual ground temperatures) has achieved equilibrium with new surface temperatures and surface settlement at the study sites has subsided. Long term observations are necessary in order to fully address the project objectives, in particular 3, 4 and 5.

Some aspects of the project may be adjusted to respond to changing surface conditions and information requirements.

Monthly acquisition of ground temperature and pipe temperature data, regular collection of related data and laboratory and computer analyses will continue throughout 1988.

Reports available

A-Cubed Inc. 1984. Radar surveys at the EMR/INAC monitoring sites along the Norman Wells pipeline route, December 1983. Report to Energy, Mines and Resources, Canada. 50pp.

A-Cubed Inc. 1984. Digitization, processing and display of Mackenzie Valley pipeline radar data collected December 1983. Report to Energy, Mines and Resources, Canada. 41pp.

A-Cubed Inc. 1985. Radar surveys at the EMR/INAC monitoring sites along the Norman Wells pipeline route, June 1984. Report to Energy, Mines and Resources, Canada. 56pp.

A-Cubed Inc. 1985. Electrical property measurements of the 1984 Norman Wells pipeline core samples. Report to Energy, Mines and Resources, Canada. 119pp.

A-Cubed Inc. 1985. Radar and TDR measurements carried out along the Norman Wells, NWT to Zama, Alberta pipeline route in September 1984. Report to Energy, Mines and Resources, Canada.

A-Cubed Inc. 1985. Radar and TDR measurements carried out along the Norman Wells, NWT to Zama, Alberta pipeline, May 1985. Report to Energy, Mines and Resources, Canada. 2 volumes.

Burgess, M.M. 1986. Norman Wells Pipeline Monitoring Sites - Ground Temperature Data File: 1984-1985. Earth Physics Branch Open File 86-6. Earth Physics Branch, Energy, Mines, and Resources, Canada. 21pp. plus appendices.

Burgess, M.M. 1986. Norman Wells Pipeline Monitoring Sites - Ground Temperature Data File: 1986. Open File 1621, Geological Survey of Canada, Energy, Mines and Resources, Canada. 24pp. + appendices.

Burgess, M., J. Pilon & K. MacInnes 1986. Permafrost Thermal Monitoring Program Norman Wells to Zama Oil Pipeline. Proceedings Northern Hydrocarbon Development Environmental Problem Solving Conference, Banff, Alberta, Sept. 24-25, 1985. pp. 248-257.

Burn, C.R. 1987. Installation of magnetic soil displacement gauges along the Norman Wells pipeline right-of-way. Final contract report to Terrain Sciences Division, Geological Survey of Canada. University of British Columbia. 24pp.

Granberg, H.B. 1985. Equipment installation report for permafrost climate project at Schefferville and Norman Wells. Report to Atmospheric Environment Service, Environment Canada. 39pp. (unpublished).

Hardy Associates (1978) Ltd. 1984. 1984 EMR instrumentation program, Norman Wells to Zama pipeline. Report to Energy, Mines and Resources, Canada. 161pp.

Hardy Associates (1978) Ltd. 1985. 1985 EMR instrumentation program, Norman Wells to Zama pipeline. Report to Energy, Mines and Resources, Canada. 205pp.

Patterson, D.E., D.W. Riseborough and M.W. Smith. 1987. Analysis of Norman Wells to Zama pipeline core samples. Final report to Geological Survey of Canada, Energy, Mines and Resources. Geotechnical Science Laboratories, Carleton University, Ottawa. 60pp. + appendices.

Pilon, J.A. and M.M. Burgess 1984. Thermal impact on permafrost of the Norman Wells to Zama pipeline construction and operation - Progress Report October 1984. Division of Gravity, Geothermics and Geodynamics, Earth Physics Branch, Energy, Mines and Resources, Canada. 7pp.

Pilon, J.A., A.P. Annan, and J.L. Davis. 1985. Monitoring permafrost soil conditions near a buried oil pipeline using ground probing radar and time domain reflectometry techniques. Extended abstract. 55th Annual International Meeting of the Society of Exploration Geophysicists, Washington, D.C., Oct. 6-10, 1985.

Contact

Margo Burgess (thermal aspects)

Permafrost Research Section

Terrain Sciences Division

Geological Survey of Canada

Energy, Mines and Resources Canada

1 Observatory Crescent

Ottawa, Ontario K1A 0Y3

(613) 996-9317

Alan Judge (climate change)
Permafrost Research Section
Terrain Sciences Division
Geological Survey of Canada
Energy, Mines and Resources Canada
1 Observatory Crescent
Ottawa, Ontario K1A 0Y3
(613) 996-9323

Dr. Jean Pilon (geophysical aspects)
Permafrost Research Section
Terrain Sciences Division
Geological Survey of Canada
Department of Energy, Mines and Resources
1 Observatory Crescent
Ottawa, Ontario K1A 0Y3
(613) 996-9315

Dr. Kaye MacInnes (ecological and land use aspects)
Land Resources Division
Department of Indian Affairs and Northern Development
Box 1500
Yellowknife. N.W.T. X1A 2R3
(403) 920-8152 Telex: 034-45505

Dr. David Harry (geomorphic aspects)
Engineering and Geomorphic Processes
Terrain Sciences Division,
Geological Survey of Canada
Department of Energy, Mines and Resources
601 Booth Street
Ottawa, Ontario K1A 0E8
(613) 992-4303

Figure 5.1 Monitoring sites locations

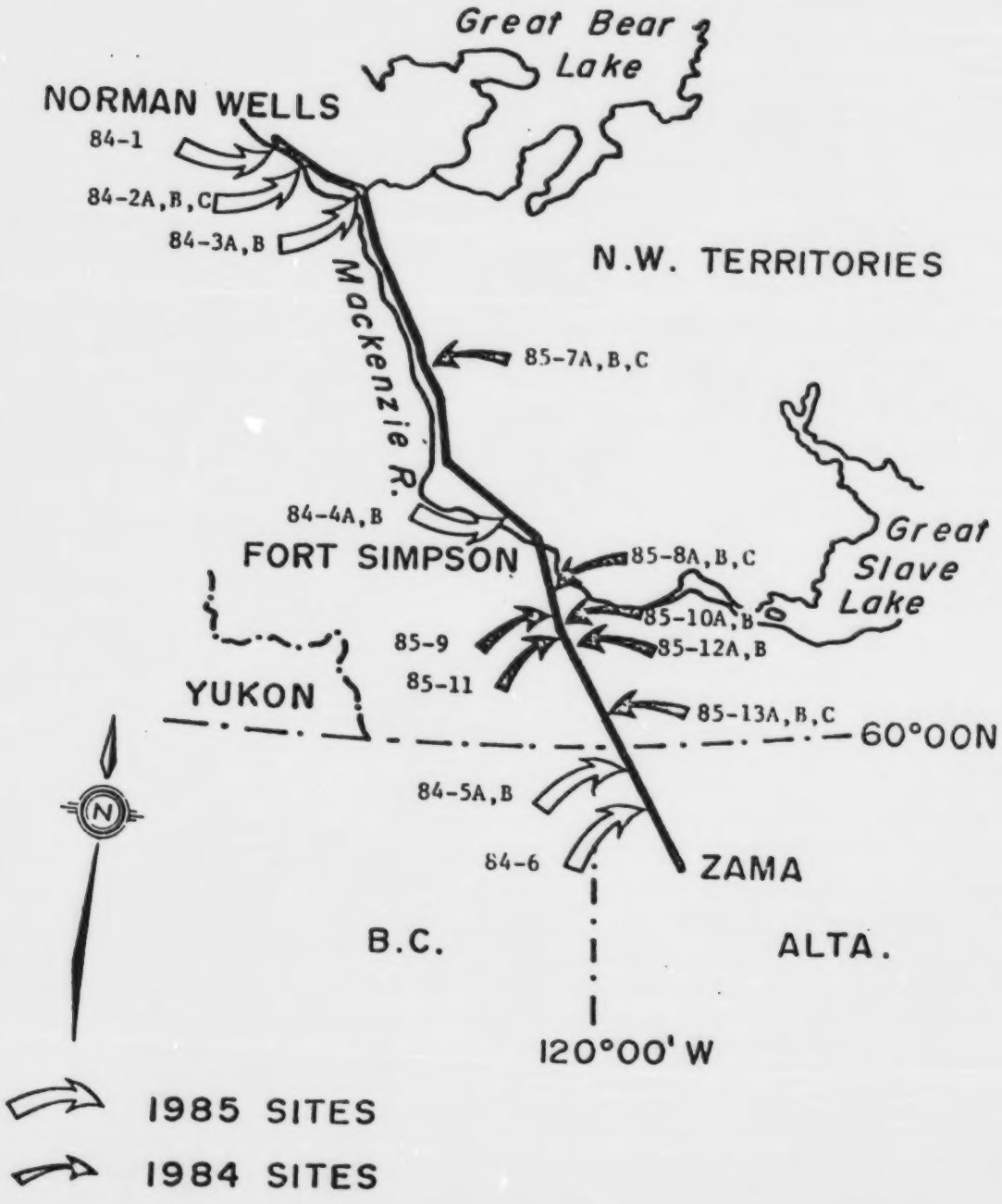
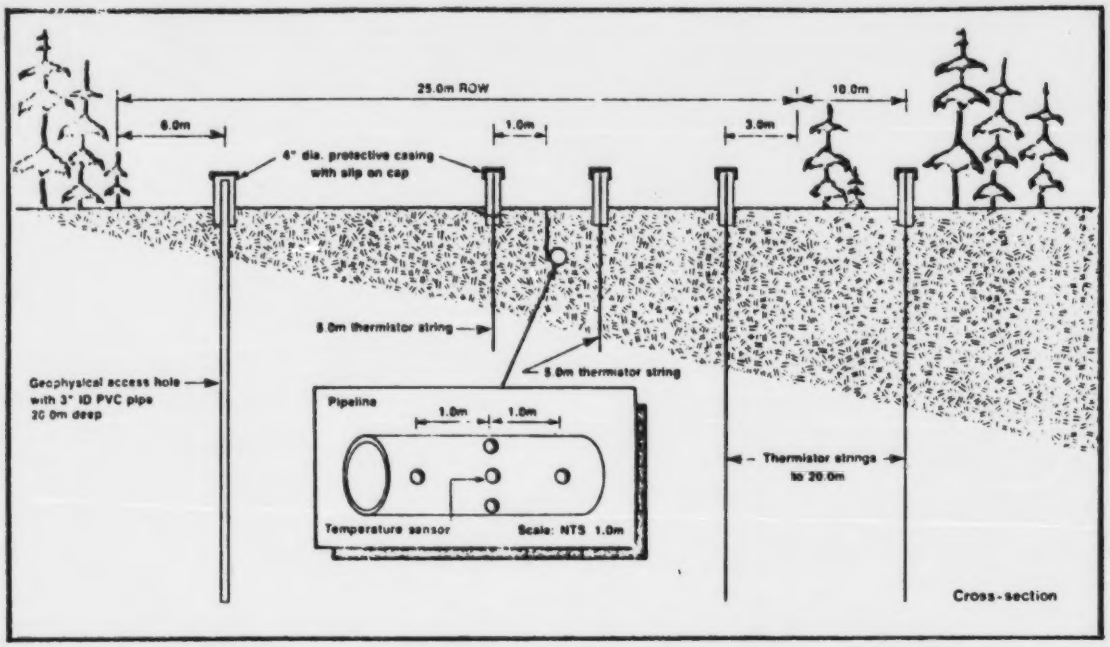
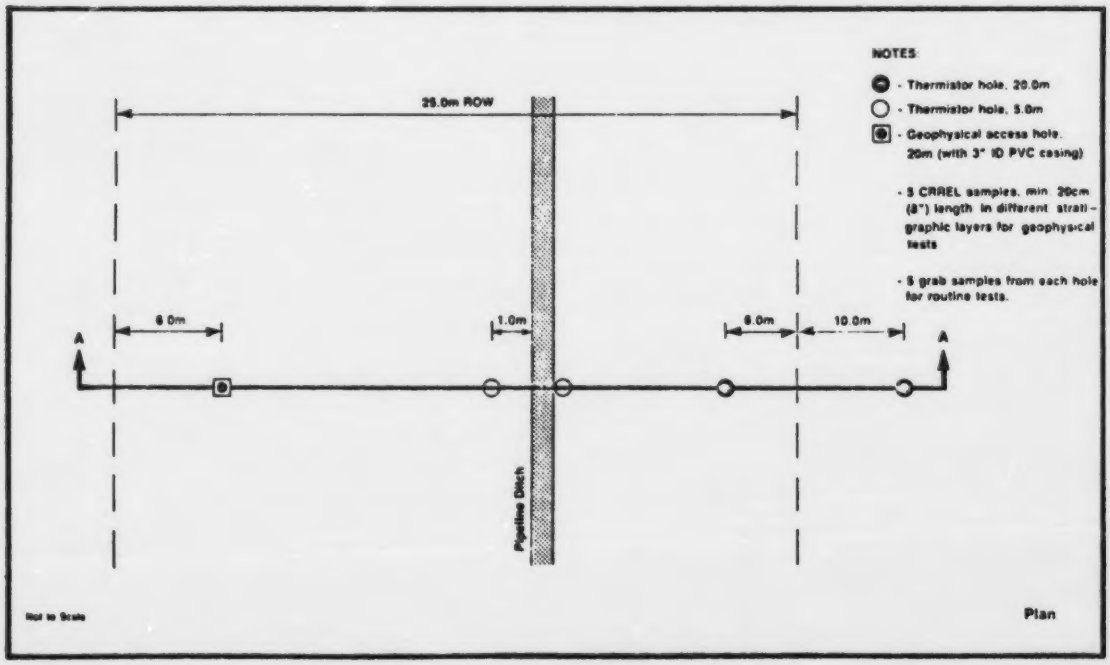
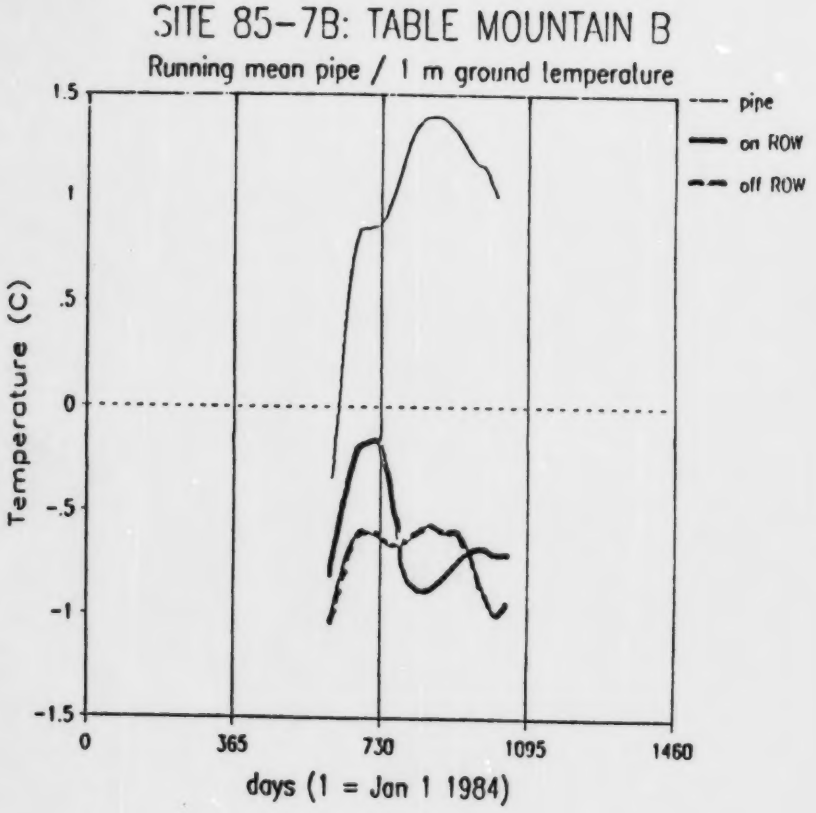


Figure 5.2 Example of the layout of a thermal fence.







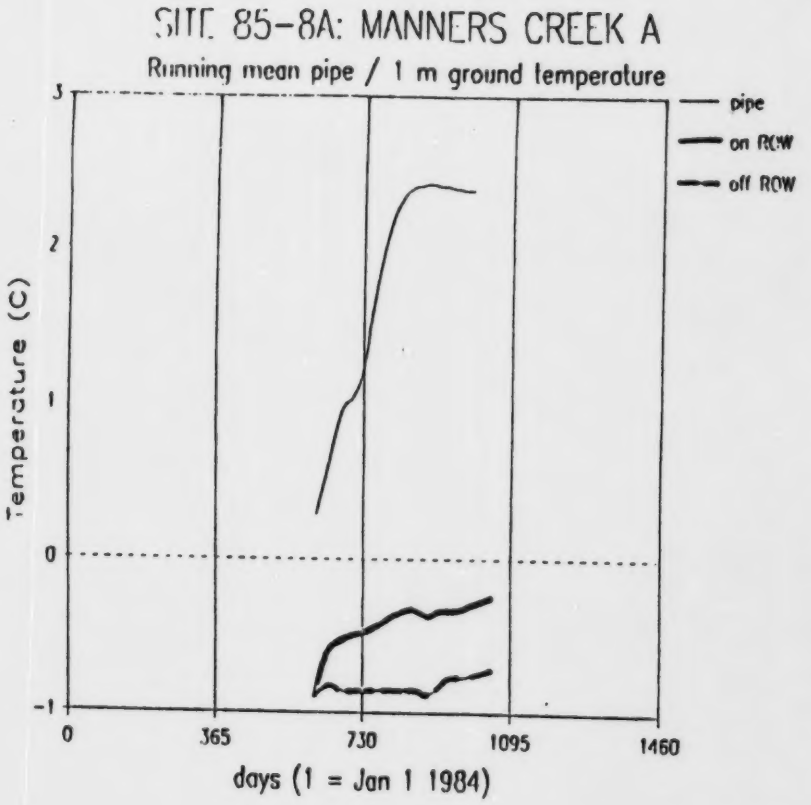


Figure 5.3 Plots of running mean annual pipe temperature and running mean annual ground temperature at a depth of 1m both on and off the ROW; examples from thermal fences 85-7B and 85-8A. ROW ground temperatures are from the cable located several metres (>4) from the trench. 52 week running means were calculated from weekly interpolated temperatures derived from curve fitting to the approximately monthly temperature record. Each calculated mean was assigned and plotted to the mid-point of the year of data (i.e. week 26).

Table 5.1 Site Descriptions

EMR-INAC Site No.	Site	Pipeline km post	Description (at time of establishment)
84-1	Pump Stn. 1	0.02	Ice-rich silty clay material in widespread permafrost
84-2	Canyon Creek		(previous CNT clearing)
	A	19.0	Level location, frozen till with low ice content in widespread permafrost
	B	19.3	East-facing ice rich slope in widespread permafrost, 1 m insulating woodchip cover
	C	19.6	West facing ice-rich slope in widespread permafrost with an erosion control berm
84-3	Great Bear River		(Joint IPL site)
	A	79.2	Stratigraphically complex ice-rich alluvial terrace deposits in widespread permafrost; cliff-base
	B	79.4	Cliff top lacustrine deposits with veneer of aeolian deposits
85-7	Table Mountain		(Joint IPL site)
	A	271.2	Ice rich lacustrine plain (old seismic line)
	B	272.0	Helipad clearing at bend on top of north facing slope, ice-rich lacustrine plain
	C	272.3	New clearing on level ice-rich lacustrine plain
84-4	Trail River		(Pipeline previously traversed frozen ground)
	A	478.0	Unfrozen saturated sands and silts in dune hollow
	B	478.1	Dry sand and silts in dune crest
85-8	Manners Creek		(Rapidly changing permafrost conditions)
	A	557.8	Thin peat with thick (10 m) permafrost
	B	558.2	Thick (2.7 m) peat with thin (4 m) permafrost
	C	558.3	Thin peat (1 m) with thin (4 m) permafrost
85-9	Pump Stn. 3	583.3	Frost free granular soils after long frozen section
85-10	Mackenzie Hwy South		
	A	588.3	Transition from a helipad clearing in unfrozen terrain to
	B	588.7	Thin (3 m) permafrost with 2 m peat cover
85-11	Moraine S.	597.4	Thin (4 m) permafrost in helipad clearing
85-12	Jean Marie Creek		
	A	608.6	Thin unfrozen peat plateau
	B	608.7	Thick ice-rich peat plateau; 4 m permafrost
85-13	Redknife Hills		
	A	682.2	Frozen (6 m) terrain surrounding large fen
	B	682.4	Frozen (6 m) terrain at fen border
	C	682.6	Unfrozen terrain in fen
84-5	Petitot R. North		
	A	783.0	Ice-rich peat (3.5 m); (15-18 m) permafrost
	B	783.3	Very thick icy peat (7 m); total 12 m permafrost
84-6	Petitot R. South		
		819.5	Thick (5 m) ice-rich peat; 7 m permafrost

Table 5.2 Schedule of permafrost and terrain research and monitoring field work from November 1985 through October 1987.

Date	Observer[1]	Purpose[2]
1985		
November 13, 15	L. Schmidt, N. Sancartier	Northern data (INAC)
November 20	J. Hayes, W. Lafleur	Southern data (INAC)
December 12, 13, 16	K. Beraska, B. Hoover J. Hayes, D. Trudeau, W. Lafleur	Southern data (INAC)
1986		
January 14, 17	P. Rivard, N. Sancartier L. Schmidt	Northern data (INAC)
January 13 - 15	B. Hoover, W. Lafleur K. Beraska, D. Trudeau	Southern data (INAC)
February 21	D. Elliott	Northern data (INAC)
February 19 - 20	J. Hayes, W. Lafleur	Southern data (INAC)
March 3 - 5	K. MacInnes, J. Pilon W. Pollard	Northern data (INAC, EMR) (Km. 0 - 273, 528)
March 12, 24, 26	D. Trudeau, W. Lafleur K. Beraska	Southern data (INAC)
April 9 - 10, 12	D. Trudeau, B. Hoover W. Lafleur	Southern data (INAC)
April 29	B. Hoover (with IPL)	Southern pipe thermistors (INAC)
April 30	L. Schmidt, N. Sancartier	Northern data (INAC)
May 23 - 28	M. Burgess, W. Pollard	All sites (EMR)
June 19 - 23	D. Harry, K. MacInnes	All sites (INAC EMR)
June 27 - 28	A. Judge, J. Pilon	Radar survey Gt. Bear (EMR)
July 14 - 19	K. MacInnes	All sites (INAC)
August 1 - 11	K. MacInnes, C. Tarnocai D. Kroetsch	All sites (INAC) Install soil probes (Ag.Can.)
September 18 - 25	H. Baker, L. Goodrich	Canyon Ck. equipment (NRC)
September 25 - 30	K. MacInnes, F. Adlem, H. Baker	All sites (INAC NRC)
October 23 - 29	M. Burgess, V. Allen	All sites (EMR)
November 12	D. Elliott, L. Schmidt, P. Rivard	Northern data (INAC)
November 19 - 20	P. Trudeau, B. Hoover	Southern data (INAC)
December 10	D. Elliott, L. Schmidt,	Northern data (INAC)
December 16,17,19,22	P. Trudeau, B. Hoover	Southern data (INAC)
1987		
January 15, 16	P. Rivard, L. Schmidt	Northern data (INAC)
January 16, 20, 21	B. Hoover, D. Trudeau	Southern data (INAC)
February 4 - 9	A. Judge, J. Pilon	All sites (EMR)
March 9 - 15	K. MacInnes, A. McRobert	All sites (INAC)
April 15, 16	P. Rivard, L. Schmidt D. Elliott	Northern data (INAC)
April 9, 13	D. Trudeau	Southern data (INAC)
May 22 - 27	M. Burgess, A. Wilkinson	All sites (EMR)
June 15 - 21	H. Baker, K. MacInnes	All sites (INAC)
July 9 - 13	K. MacInnes, A. McRobert D. Trudeau	All sites (INAC)
August 14 - 20	K. MacInnes C. Tarnocai,	All sites (Ag.Can., INAC) Install TL-100 loggers[3]
September 14 - 21	D. Harry, K. MacInnes	All sites (EMR, INAC)
October 1 - 7	V. Allen, M. Burgess	All sites (EMR) Install logger at 7C[3]
October 7 - 9	C. Tarnocai	Read TL-100 loggers (Ag.Can.)

1 Observers include staff from Indian and Northern Affairs Canada (INAC) Region and Districts, Energy, Mines and Resources (EMR), Agriculture Canada (Ag.Can.) and National Research Council (NRC).

2 Northern data refers to sites from Km. 0 - 79. Southern data here refers to sites from Km. 270 - 608. All sites refer to sites from Km. 0 - 819.

3 Automatic multichannel data loggers are located at 5 thermal fences. Twenty single channel loggers (TL-100) were added for selected shallow soil depths and pipe temperatures.

Table 5.3 Observations of mean annual pipe temperature, mean annual ground temperature (depth of 1 m) and surface settlement recorded at study sites following two years of pipeline operation.

FENCE	(km)	TRENCH AREA		ROW OUTSIDE TRENCH AREA		OFF-ROW
		Mean Pipe Temperature (° C)	Range of Settlement (cm)	Mean 1 m Ground Temperature (° C)	Range of Settlement (cm)	Mean 1 m Ground Temperature (° C)
84-1	(0.02)	-0.3	0 - 60	-1.1	0 - 80	-2.0
84-2A	(19.0)	0	0 - 30	-0.9	0 - 20	-1.1
84-2B	(19.3)	-0.1	0 - 30	-0.3	0 - 40	-2.6
84-2C	(19.6)	0.7	0 - 20	1.2	0 - 30	-1.0
84-3A	(79.2)	0.9	10 - 50	-1.2	0 - 50	-1.6
84-3B	(79.4)	0.8	0 - 20	0.4	0 - 20	-2.5
85-7A	(271.2)	0.5	10 - 70	-0.1	0 - 50	0
85-7B	(272.0)	1.0	10 - 80	-0.7	0 - 50	-1.0
85-7C	(272.3)	0.3	20 - 60	-1.8	0 - 30	-1.2
84-4A	(478.0)	2.3	0 - 50	2.5	0 - 20	1.6
84-4B	(478.1)	2.2	0 - 30	3.0	0 - 30	0.8
85-8A	(557.8)	2.3	10 - 50	-0.3	0 - 30	-0.8
85-8B	(558.2)	2.3	10 - 100+	-0.5	0 - 40	-0.9
85-8C	(558.3)	1.8	10 - 80	0.1	0 - 60	-0.3
85-9	(583.3)	2.5	0 - 20	3.8	0 - 10	2.6
85-10A	(588.3)	5.0	0 - 50	2.3	0 - 30	1.5
85-10B	(588.7)	4.9	0 - 100+	-0.1	0 - 40	-0.6
85-11	(597.4)	4.5	backfilled winter/86	3.0	0 - 20	0
85-12A	(608.6)	3.6	0 - 70	1.7	0 - 20	0.3
85-12B	(608.7)	3.6	0 - 100+	-1.0	0 - 50	-1.3
84-5A	(783.0)	1.9	N/A	0.4	N/A	0
84-5B	(783.3)	1.9	N/A	-1.0	N/A	-0.4
84-6	(819.5)	1.7	N/A	-0.2	N/A	0

Notes:1. The Trench Area defined here includes trench and 2 meters on either side of the pipe centerline. The ROW Area is the remainder of the cleared level surveyed ROW excluding the trench area.

2. The range of settlement (cm) determined from the surface elevation surveys is defined by the minimum and maximum amount observed in the area. The OFF-ROW is not covered by the survey.

3. Pipe temperatures shown are mean annuals (average of the 5 pipe sensors) calculated for the second year of operation, i.e. April 1986 to March 1987, using curve fitting to monthly data and weekly interpolation.

4. Mean annual ground temperatures are the calculated values (again using curve fitting to monthly data and weekly interpolation) for the second year of operation, for the sensor at a nominal depth of 1 m (which was the average depth of cover over the pipe relative to the top of the trench wall). The on-ROW 1 m ground temperatures are from the cable located several metres (4 to 10 m) from the trench.

5. N/A: not yet available; a second survey from which settlement will be calculated was undertaken in August 1987.

5.B. TERRAIN PERFORMANCE

Agencies Responsible

Engineering Geology and Geomorphic Processes Section, Geological Survey of Canada, Department of Energy Mines and Resources, in cooperation with Permafrost Research Section, G.S.C., Indian and Northern Affairs Canada, National Research Council of Canada, Agriculture Canada, and Interprovincial Pipe Line (NW) Ltd.

Start-up Date

August 1983

Objectives

This research program is directed toward the observation and prediction of geomorphic and geologic conditions along the Norman Wells to Zama pipeline route. Particular attention is focused upon the distribution of surficial materials, including ground ice, and their relationship to terrain performance during pipeline construction and operation. Specific project objectives are:

1. to determine the nature of geomorphic and geologic factors influencing terrain performance along the pipeline right-of-way;

2. to evaluate actual terrain impacts with respect to predictions made at the project review stage, and in relation to mitigative measures incorporated within the pipeline design; and

3. to evaluate the concept of northern terrain sensitivity in relation to pipeline construction, operation and maintenance activities.

Location

The project objectives relate to the pipeline right-of-way and adjacent areas between Norman Wells, N.W.T. and Zama, Alberta.

Results to Date

1983/84 Observations and Results

Approximately 100 sampling sites were established along the pipeline right-of-way between Norman Wells and Zama to assess three factors: 1) climate (and particularly ground temperature), 2) geomorphic environment, and 3) geologic environment. Data were collected by means of borehole logs, instrumented boreholes, ditch logs, field monitoring of slope cuts, ditch walls and related observations during construction and aerial photographs.

Fieldwork was undertaken during the 1983/84 construction season to examine the surficial geology exposed in slope and ditch sections, as follows:

April 27 - May 1	Km 1-140, 478-526, 550-801
June 5 - 7	Km 0-150
September 17 - 27	Km 0-848

Climatic Conditions

During the early phase of the 1983/84 construction season, snowfall and snow depth were significantly below normal, particularly between Norman Wells and Fort Norman.

The Mackenzie Valley and northern Alberta experienced an extremely wet and cool summer in 1984. Precipitation as recorded in Norman Wells, Fort Simpson, and High Level was as much as 240% above

normal. Much of this precipitation occurred in separate storm events.

Increased runoff resulted in:

1. saturation of near-surface sediments for prolonged periods, with ponding in closed basins,

2. high discharge levels in streams and rivers with high sediment loads and river bank erosion,

3. possible raised ground water tables in karst areas, and

4. possible decreased stability of both natural and pipeline-related slopes.

Terrain Performance (Summer 1984)

Right-of-Way Conditions:

1. With a few notable exceptions, there was little evidence of subsidence or erosion along the right-of-way. Slopes and side cuts generally appeared to be performing well.

2. Locally, settlement occurred along the ditchline in areas where ice-rich or snow-contaminated backfill has been used. On level stretches of the right-of-way, this resulted in water ponding within shallow linear basins.

3. Observations indicated that the organic mat was disturbed by winter grading operations over approximately 15-25% of the right-of-way between km 0-70. To date, this does not appear to have contributed to adverse terrain performance.

Areas of Erosion/Slope Failure:

1. Localized erosion and/or slope instability conditions developed at a number of sites on the pipeline right-of-way, most notably at km 67 (Norman Range), km 78 (Great Bear River N.), km 168 (Seagram Creek S.), and km 732 (Kakisa River S.)

2. In most cases, adverse terrain performance appeared due to a combination of unexpectedly high surface runoff and misplacement of erosion control structures.

Mitigation and Maintenance:

1. Along 99% of the pipeline route constructed in 1984, mitigative measures performed well in reducing terrain impact. In the few areas where they were less successful, the problem appeared to relate to field implementation rather than to the validity of the design concept.

2. Woodchip-covered slopes appeared to be performing well, although at some sites differential settlement of the woodchip surface had occurred, requiring periodic maintenance.

3. Erosion control berms were prone to wash-out in the spring as a result of the high rate of sandbag deterioration. It was expected that this potential problem would be substantially mitigated by the stabilizing effect of revegetation.

4. Temporary maintenance work was carried out during the summer to stabilize areas of erosion and slope instability. This work consisted primarily of sandbag berm replacement. Other activities included the excavation of a temporary drainage ditch at km 67 and the placement of concrete blocks to check riverbank erosion at Seagram Creek (km 168).

1985 Observations and Results

Fieldwork was undertaken during the 1984/85 construction season to examine the surficial geology exposed in slope and ditch sections. Particular attention during summer field excursions was focused upon:

1. observation of the physical condition of the right-of-way surface,

2. observations of terrain stability on slopes and at stream and river crossings,

3. identification of actual and potential zones of enhanced erosion,

4. measurement of the near-surface ground thermal regime along transects across the right-of-way, and

5. analysis and interpretation of detailed ground surface survey data.

Climatic Conditions

In contrast to 1984, winter snowfall in the Mackenzie Valley was significantly above normal in January and February, with snowfall greater than twice normal values recorded at Fort Simpson. This provided a good base for construction activities. Summer air temperatures were predominantly below normal, with monthly means 0.5 to 2.5 degrees lower than average. This resulted in the development of shallower active layers at many sites in comparison to 1984 observations. Summer precipitation was also near or slightly below normal, particularly in the southern Mackenzie Valley and northern Alberta. This factor probably accounted, in part, for the reduced incidence of early summer surface erosion on the right-of-way. However, as in 1984, some erosion events occurred which may be

related to storm periods, characterized by relatively brief but intensive precipitation.

Terrain Performance

A. 1985 Construction spreads

In general, right-of-way terrain performance during the post-construction thaw season was similar to that observed the previous year on 1984 construction spreads. Specific comments are as follows:

1. Local settlement again occurred along the ditchline in areas where ice-rich or loose, blocky backfill was used. However, the incidence of this condition was reduced by the emplacement of a larger and more accurately positioned berm during 1985 winter construction.

2. Surface erosion occurred at a number of locations in summer 1985, although both frequency and magnitude of erosion events were significantly less than in 1984. This probably reflected a combination of factors, including lower than average summer precipitation and therefore reduced runoff levels. However, it also reflected the prompt and effective summer maintenance work undertaken by IPL.

3. Erosion was most pronounced along segments of right-of-way traversing long, low-angle slopes, for example on the south side of Redknife Hills, rather than on steep slopes or at river crossings. In many cases, flow was concentrated along stretches of subsided ditchline which provided a natural route for water movement.

4. Erosion of woodchips occurred on the north side of the Blackwater River as a result of runoff from a steep side slope. It should be emphasized, however, that woodchips mobilized by the flow were redeposited at distances of 0-200 m from the right-of-way and did not enter any adjacent water courses.

5. Most slopes appeared stable following the first thaw season. A small mass flow was observed on the north bank of Jean Marie Creek and appeared to have resulted from the saturation and mobilization of sediments by water percolating along the ditchline.

6. Summer maintenance activities on 1985 construction spreads included site specific restoration of eroded areas, together with a systematic program to refill and reroach areas of subsided ditch.

B. 1984 Construction spreads

In general, terrain appeared to have stabilized along most segments of the 1984 construction spreads and revegetation was well advanced. Specific points are as follows:

1. Comparison of surveys made at EMR monitoring sites in summer 1984 and 1985 suggested that up to 1 m of settlement had occurred in areas underlain by ice-rich surficial sediments (eg. EMR 84-1, EMR 84-3a). Sites underlain by thaw-stable materials experienced little surface change (eg. EMR 84-3b).

2. Further geomorphic evidence of localized ground surface subsidence was provided by the development of hummocky thermokarst terrain (eg. KmP 78) or small, near-circular thaw ponds (eg. KmP 80).

3. Major remedial work was undertaken during winter 1985 at sites of 1984 erosion and in particular at km 67 and km 78 (north side of Great Bear River). These sites now appear completely stable and well protected from erosion.

C. Summary

After monitoring over one thaw season following construction on spreads 2, 3 and 5, and over two full thaw seasons on other spreads, sub-optimal terrain performance had been limited to less than 1% of the total pipeline route.

1986 Observations and Results

A single period of fieldwork was undertaken in 1986, from June 19-23. A second field visit, scheduled for September, was cancelled. During the June trip, the right-of-way was inspected by helicopter between Kmp 0 (Norman Wells) and Kmp 818 (south of Petitot River). Approximately 40 stops were made to read IPL/EMR/INAC instrumentation, to measure near-surface thermal transects, and to make general observations of right-of-way terrain conditions and performance.

These observations relate only to the early phase of the 1986 thaw season. Additional information on terrain conditions later in the summer however, has been made available to this project by other members of the research group, and in particular by K.L. MacInnes, (INAC), M. Burgess (EMR), C. Tarnocai (Agriculture Canada), and T.H.W. Baker (NRC).

Climatic Conditions

The following comments are based upon the analysis of May-August

meteorological data from Atmospheric Environment Service weather stations at Norman Wells, Fort Simpson, High Level, Fort Norman, and Wrigley. Additional observations from several Forestry fire towers have been made available by INAC.

Air temperatures were near normal in the Mackenzie Valley in May, June, and July. Temperatures were below normal in August, by as much as 4°C in the Fort Simpson area. Total monthly precipitation was also near or below normal at most stations, and well below normal in the Norman Wells area in June and July. As in previous years, much of the precipitation occurred during storm events which were often very localized in their effect. For example, the Mount Gaudet fire tower recorded nearly 80 mm of rainfall within a 48 hour period from June 24-25. This exceeds any other recorded summer storm event in 1984 or 1985.

Terrain Performance

General Right-of-way condition (June 1986):

1. Most of the right-of-way appeared to be in good condition during the June monitoring trip. No instances of exposed pipe, major erosion, or slope movement were observed.

2. Some right-of-way segments were still characterized by a subsided ditchline, in some cases containing ponded water. IPL continued its program to rebuild the roach in these areas. Subsided ditch was also noted across several stream floodplains.

3. In most cases, remedial work implemented during the previous winter appeared to have successfully corrected problems identified in 1985. One exception was on the slope north of Blackwater River (Kmp 224), where there was evidence of continued woodchip erosion and mass movement on the west side slope.

Surface Erosion:

1. Few instances of surface erosion were observed during the June monitoring trip. This reflected both low precipitation levels from May to early June and also the successful implementation of erosion control measures by IPL. As in 1985, surface erosion again occurred on gently sloping terrain south of Fort Simpson (Kmp 654-657) as a result of water flowing along the ditch. Cross drainage also resulted in shallow (<30 cm) gullying, for example at Canyon Creek South (Kmp 19), Norman Range (Kmp 65), and IPL Slope 73 North (Kmp 270). Gullying up to 2 m in depth developed on the shoofly adjacent to IPL Slope 75 (Kmp 2873), over a distance of approximately 20 m.

2. At several stream crossings, approach slopes were eroded by floodwaters related to the break-up of ice dams or heavy precipitation events in late June, July, and August. High water levels resulted in the flotation and erosion of woodchips at Unnamed Creek North (Kmp 133). This had undermined the wooden crib structure, resulting in further slumping and loss of woodchips.

3. During a major rainstorm on June 24-25, the Hodgson Creek catchment north of Wrigley received nearly 80 mm of precipitation within a 48 hour period. High runoff levels resulted in riverbank erosion both upstream and downstream of the pipeline crossing (Kmp 305), and the reactivation of several abandoned stream channels. Following the flood, the river appeared to have changed its channel pattern, such that part of its flow was initially directed across and along the right-of-way for a distance of approximately 300 m from the original crossing point. This caused some erosion of the ditchline and right-of-way. Sandbags were used as a temporary remedial measure to retrain water across the right-of-way.

Surface Stability:

1. Surface subsidence was noted at a number of localities, including the right-of-way between EMR thermal fences 85-7B and 85-7C, and an adjacent shoofly. These sites were monitored by means of visual observation and topographic survey.

2. Topographic surveys were undertaken in September 1986 at all EMR monitoring sites within the N.W.T. These data are currently being analyzed, and will be used to evaluate surface stability at these sites.

1987 Observations and Results

A single period of fieldwork was undertaken in 1987, from September 13-20. The right-of-way was inspected by helicopter between Kmp 0 (Norman Wells) and Kmp 818 (south of Petitot River). Approximately 40 stops were made to read EMR/INAC/IPL instrumentation on slopes and at thermal monitoring sites, to measure near-surface thermal transects, and to make general observations of right-of-way terrain conditions and performance. In addition, a preliminary survey was made of terrain conditions along potential pipeline routes between Norman Wells and Inuvik. As in previous years, additional field data were made available to this project by other members of the research group, and in particular by K.L. MacInnes (INAC), M. Burgess (EMR), C. Tarnocai (Agriculture Canada), and T.H.W. Baker (NRC).

Terrain Performance

General Right-of-way conditions (September, 1987)

Most of the right-of-way appeared to be in good condition during the September monitoring trip. No instances of exposed pipe, major erosion, or mass movement on slopes were observed.

Surface Stability

Topographic re-surveys were made of all EMR/INAC thermal monitoring sites in September, 1987. Preliminary analysis of these data showed that surface settlement was continuing to occur at most sites, particularly in the trench area.

Other Issues

Preliminary observations were made of the effects of 1986 forest fires on permafrost terrain in the area of Travaillant Lake, southeast of Inuvik. Catastrophic terrain degradation, characterized by widespread skinflows (active layer detachment failures) and retrogressive thaw slumps, had been triggered by the thaw of ice-rich permafrost. This area is traversed by potential routes for future Beaufort pipeline projects.

Future studies

Terrain performance research and monitoring will be continued for at least two more years in order to assess long-term terrain stability in relation to an operating northern pipeline.

Reports available

Harry, D.G. 1984. Norman Wells to Zama Pipeline: Project to Monitor Terrain Performance Progress Report, November 1984. Unpubl. Rept. Terrain Sciences Division, Geological Survey of Canada. 4pp.

Harry, D.G. and K.L. MacInnes. 1988. The effect of forest fires on permafrost terrain stability, Little Chicago - Travaillant Lake area, Mackenzie Valley, N.W.T. Geological Survey of Canada, Paper 88-1D. pp.91-94.

Contact

Dr. David Harry
Terrain Sciences Division, Geological Survey of Canada
Department of Energy, Mines and Resources
601 Booth Street
Ottawa, Ontario K1A 0E8
(613) 992-4303

5.C. EVALUATION OF WOOD CHIP INSULATION ON THAW SENSITIVE SLOPES

Agencies Responsible

Institute for Research in Construction, National Research Council of Canada, in cooperation with Indian and Northern Affairs Canada.

Start-up Date

September 1986

Objectives

1. to evaluate the use of wood chips to prevent or retard the thaw of ice-rich permafrost slopes;

2. to measure the long-term thermal properties of wood chip insulation;

3. to develop a thermal model of wood chip performance for use in future designs; and,

4. to compare wood chips with other alternatives to insulate ice-rich permafrost slopes.

Locations

1. Canyon Creek wood chip covered slope - NRC instrumentation coordinated with INAC/EMR instrumentation at the same location.

2. Slope 76 (Kmp 273.1)

Results to Date

NRC instrumentation was placed on the east-facing slope at Canyon Creek in September 1987 (beside INAC/EMR Site 84-2B). This installation was to provide information on long-term changes in in-situ thermal properties (temperature distribution, heat flow, thermal conductivity) of the wood chip layer. This instrumentation has been in place only for the first year of a three year program. Some difficulty has occurred with the data logger and the measurement of the thermistors associated with the heat flow meters. Data obtained to date therefore provides information only on seasonal fluctuations.

In February 1987, two samples of wood chips were obtained by IPL personnel from slope 76 (Kmp 273.1). These samples were shipped by air to Ottawa in insulated boxes for mycological analysis (description of micro-organisms) by Forintek Canada Corporation. One sample was experiencing self-heating at the time of sampling and the other one had cooled down from a self-heating cycle the previous summer. Analysis identified that wood species composition of the samples was 50% spruce and 50% aspen. The analysis also identified one Basidiomycete fungus, Merulius tremullosus Fr., that is known to occur in aspen wood chips exhibiting self-heating. The analysis, however, was not able to identify the cause of the self-heating phenomenon.

Samples experienced temperatures below 20°C during transit. This would have eliminated any thermophilic or thermotolerant fungi (fungi that can exist at temperatures in the range 35 - 40°C).

Conclusions and Recommendations

It is too early to draw any conclusions from the thermal data

retrieved from the instrumentation at Canyon Creek. Data should be retrieved for another two or three years to provide information on the change of thermal properties with time.

Winter site visits are also required to obtain snow depth data that is critical in analyzing the thermal regime of the wood chip layer.

Further research should be undertaken to improve the application of wood chips as an insulation on permafrost. Other alternative methods of modifying the ground surface to prevent thaw of the permafrost should also be investigated.

Mycological analyses are best done in the field. Incubators can be brought to a field laboratory and set up to make the cultures and isolate the micro-organisms. This process would take about two weeks. Identification of the isolates could then be done in a southern laboratory.

Future Studies

The establishment of a full-scale demonstration project is being proposed to compare several methods (including a modified application of wood chips) of insulating permafrost slopes. This project would include the placement of instrumentation prior to clearing a right-of-way and installation of various surface modifications and overlays to reduce the effects of thaw.

Reports Available

none

Contact

T.H.W. Baker
Institute for Research in Construction
National Research Council of Canada
Ottawa, Ontario K1A 0R6
(613) 993-3807

5.D. SOIL TEMPERATURE STUDY

Agencies Responsible

Land Resource Research Centre, Agriculture Canada, in cooperation with Indian and Northern Affairs Canada, Energy Mines and Resources Canada, and Interprovincial Pipe Line (NW) Ltd.

Start-up Date

April 1, 1986

Objectives

1. to determine thermal changes in the soil (in both the active layer and the near-surface permafrost) caused by pipeline-related activities, including right-of-way clearance and pipeline installation, operation, and maintenance;

2. to assess the short and long-term environmental and soil climatic changes resulting from these thermal changes; and,

3. to compare the actual thermal changes in the soil with the predicted changes in order to recommend improvements in planning and design so that the environmental impact of future northern pipelines can be minimized.

Locations

See Figure 5.4 and Tables 5.4 and 5.5 for 13 site locations which are coordinated with INAC/EMR thermal fences. The emphasis of the study is on temperatures obtained at shallow depths (less than or equal to 1.5 m) and on near surface conditions.

Results to Date

The instrumentation along the pipeline was installed in August of 1986 and temperature monitoring began at that time. The monitoring was carried out manually on some sites, while on others, recorders were used (Table 5.4). Seven to 15 observations were made on manually monitored sites, while 230 observations were made on sites monitored by recorders. Six major types of soils occur at the 13 locations and their temperatures were monitored at depths of 2.5, 5, 10, 20, 50, 100, and 150 cm.

Most of the soils located on the pipeline right-of-way (ROW) increased in temperature. The increase in the mean annual soil temperature at depths of 50, 100, and 150 cm was 0.4 to 3.3°C on fine textured lacustrine soils, 0.7 to 5.3°C on fine textured alluvial soils, 1.0 to 2.7°C on medium textured till soils, 0.4 to 3.1°C on coarse textured sandy soils, and 0 to 2.6°C on perennially frozen organic (peat) soils. The unfrozen organic (peat) soil was cooler on the ROW (0.6 to 1.2°C) than the similar soil located off the ROW. At the 50 cm depth, none of the undisturbed soils had temperatures above 5°C but a number of soils located on the ROW had such temperatures and they persisted for 50 to 100 days. Since data for only one year was used in this evaluation, the results should be considered to be preliminary.

Conclusions and Recommendations

Most soils located on the ROW were warmer at all three depths than the corresponding soils located in the undisturbed area. This warming, although slight, was significant on those soils which were perennially frozen and might be crucial on those soils whose mean annual soil temperature was near 0°C. The degree of warming on all disturbed perennially frozen mineral soils and most disturbed

perennially frozen organic (peat) soils was such that permafrost no longer existed at a depth of 100 cm. Permafrost was present at this depth in all of the corresponding undisturbed soils located off the ROW. Approximately half of both perennially frozen mineral and organic soils showed indications of further permafrost degradation extending to the 150 cm depth.

Future Studies

In the summer of 1987, 20 additional recorders were installed. Eleven of these recorders monitor pipe temperatures (Figure 5.5) while the remaining nine monitor soil temperatures on soils exposed to various degrees of disturbance (Figure 5.6). The expected duration of these soil temperature studies is at least three years since this is the minimum amount of time required to obtain the quantity of data needed for reliable results.

Reports Available

Tarnocai. C. 1986. Norman Wells pipeline soil temperature study: Installation of thermistor probes and soil sampling August 1-11, 1986. (available from author) (preliminary - to be included in subsequent research report).

Tarnocai. C. 1986. Norman Wells pipeline soil temperature study: Instrumentation and data handling. (available from author).

Tarnocai. C. 1987. The thermal effect of the Norman Wells pipeline on permafrost soils in northern Canada. (manuscript submitted for presentation at the V International Permafrost Conference).

Contact

Charles Tarnocai

Land Resource Research Centre

K.W. Neatby Building

Ottawa, Ontario K1A 0C6

(613) 995-5011

Figure 5.4 Location of soil temperature sites along the Norman Wells pipeline.

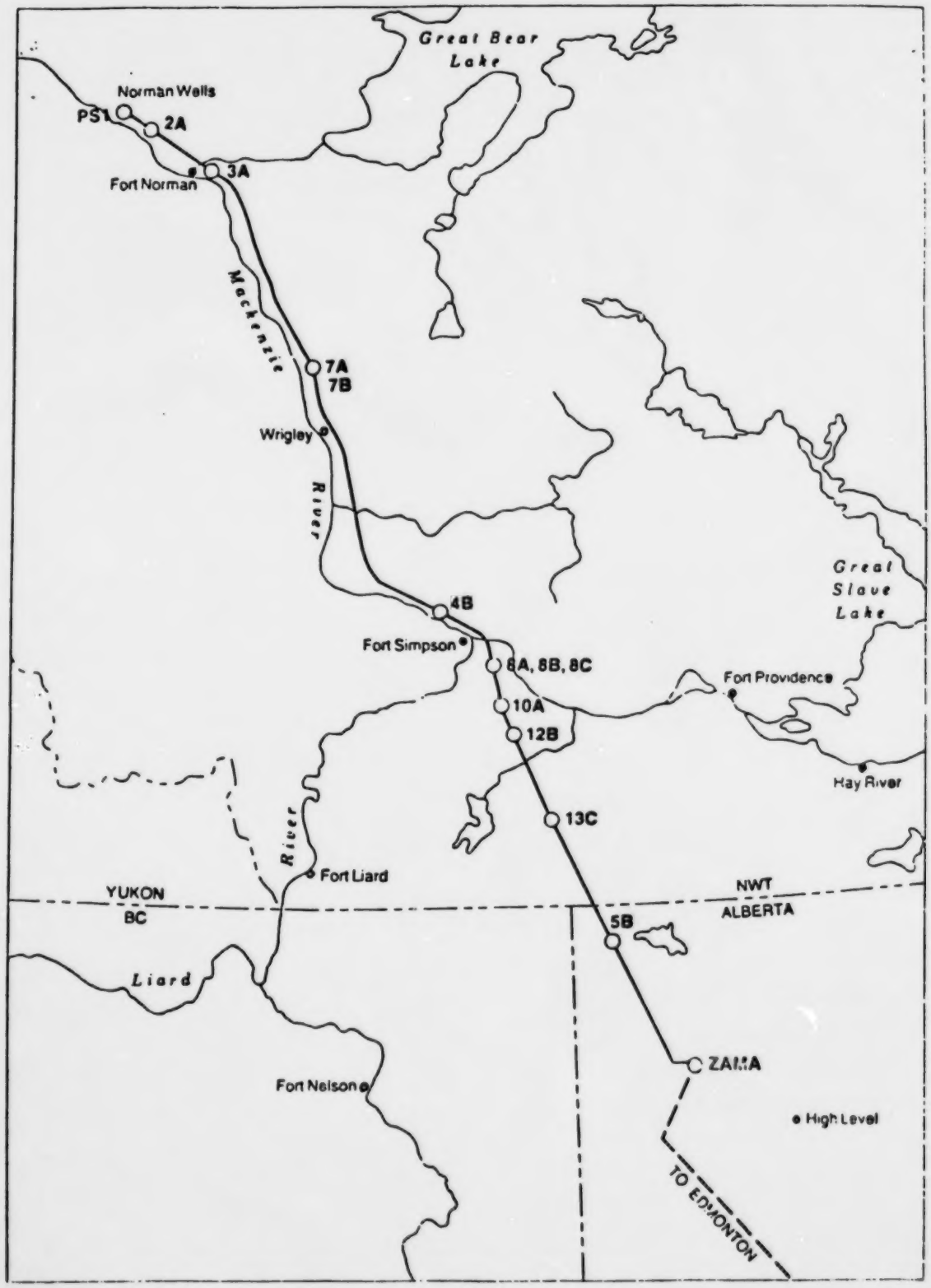


Figure 5.5 Location of TL-100 pipe temperature loggers (italic numbers 50's and 60's) along the Norman Wells pipeline.

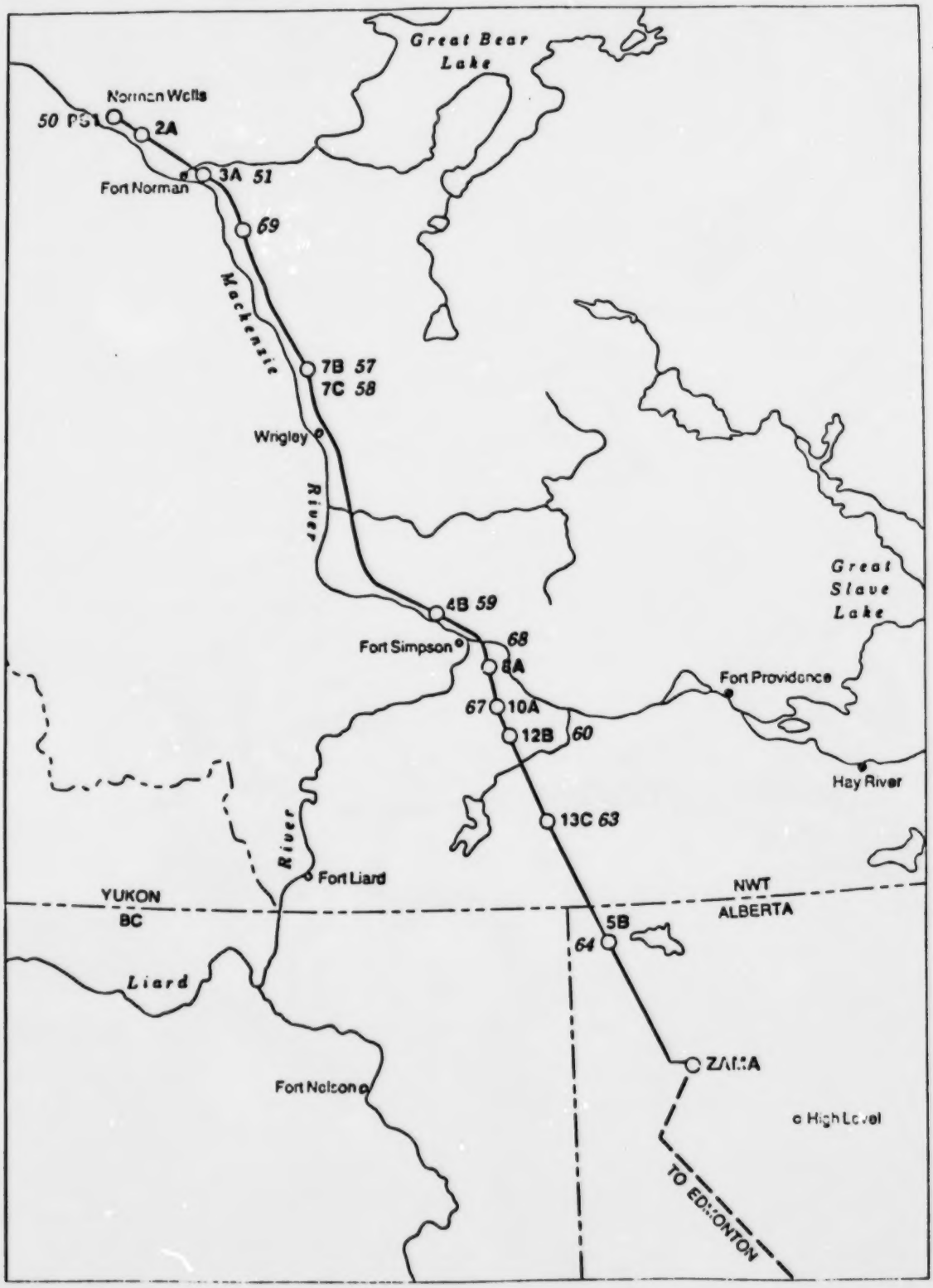


Figure 5.6 Location of TL-100 soil temperature loggers (italic numbers 50's and 60's) on various disturbed areas along the Norman Wells pipeline.

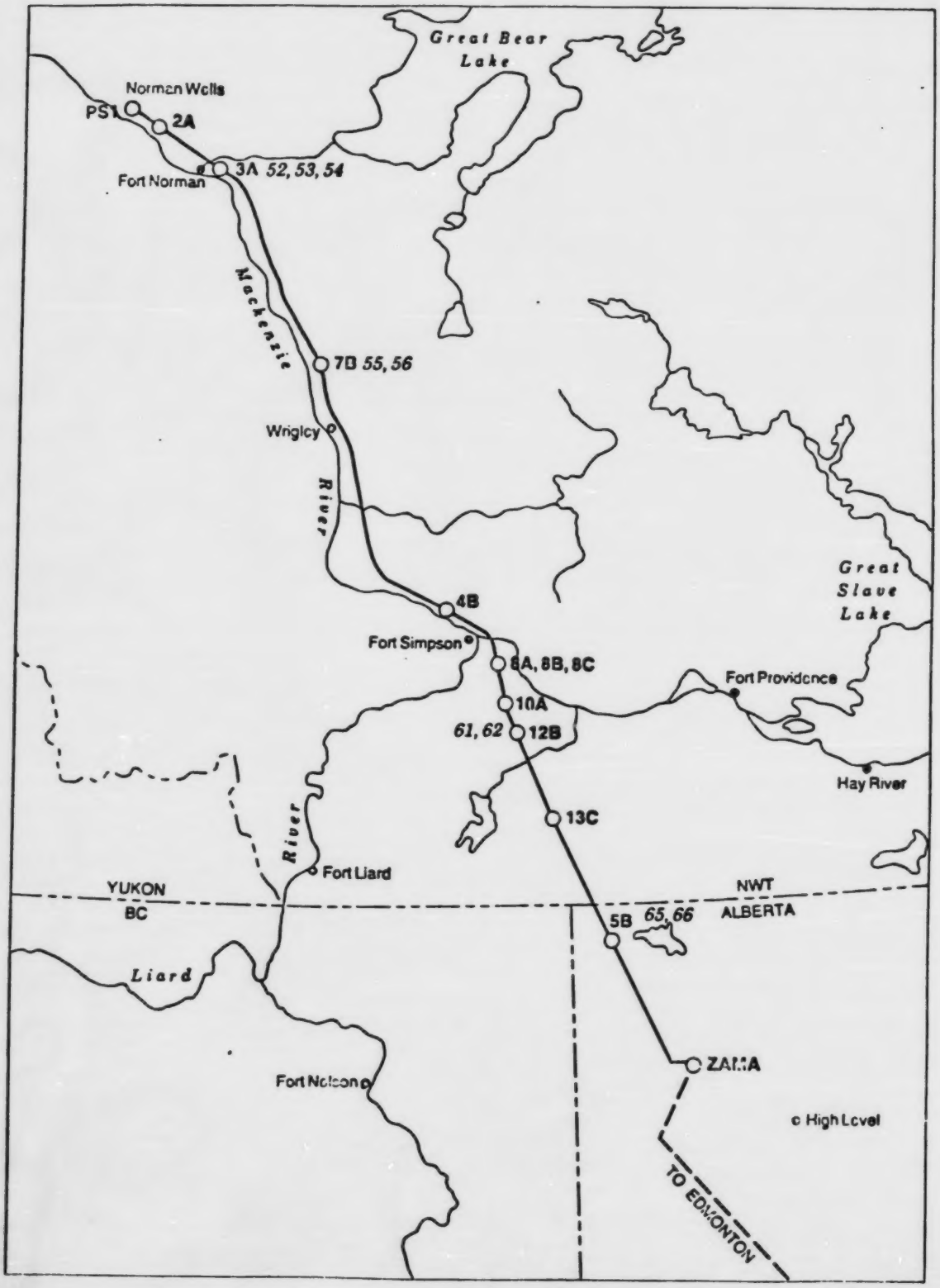


Table 5.4 Site locations and methods of monitoring of soil temperature sites along the Norman Wells pipeline

No.	Location	Pipeline km post	Number of sites (probes)	Method of monitoring
1	Pump Station 1 (PS1)	0.02	2	manual
2	Canyon Creek (2A)	19.0	2	manual
3	Great Bear River (3A)	79.2	3	recorder
4	Table Mountain (7A)	271.2	2	recorder
5	Table Mountain (7B)	272.0	2	recorder
6	Trail River (4B)	478.0	2	manual
7	Manner's Creek (8A)	557.8	2	manual
8	Manner's Creek (8B)	558.2	2	manual
9	Manner's Creek (8C)	558.3	2	manual
10	Mackenzie Hwy. (10A)	588.3	2	manual
11	Jean Marie Creek (12B)	608.7	2	manual
12	Redknife Hills (13C)	682.6	2	manual
13	Petitot River North (5B)	783.3	2	manual

Table 5.5 Description of materials to a depth of 165 cm at the Norman Wells pipeline soil temperature sites

Site No.	First Material Type	First Material Depth (cm)	Second Material Type	Second Material Depth (cm)	Third Material Type	Third Material Depth (cm)
PS1-1	peat	0-40	lacustrine (SiC)*	40-165		
PS1-2	peat	0-15	lacustrine (SiC)	15-165		
2A-1	peat	0-27	till (L)	27-100		
2A-2	peat	0-20	till (L)	20-165		
3A-1	peat	0-25	alluvium (SL)	25-165		
3A-2	peat	0-98	alluvium (SL)	98-165		
3A-3	peat	0-54	alluvium (SL)	54-165		
7A-1	peat	0-35	lacustrine (C)	35-165		
7A-2	sandy gravel	0-20	peat	20-80	lacustrine (C)	80-165
7B-1	peat	0-10	lacustrine (C)	10-165		
7B-2	peat	0-10	lacustrine (C)	10-165		
4B-1	forest humus	0-3	eolian (S)	3-165		
4B-2	eolian sand	0-165				
8A-1	forest humus	0-18	eolian (S)	18-165		
8A-2	humus - sand	0-15	eolian (S)	15-165		
8B-1	peat	0-165				
8B-2	peat	0-165				
8C-1	peat	0-165				
8C-2	peat	0-52	alluvium (S)	52-110	alluvium (Si)	110-165
10A-1	forest humus	0-5	till (CL)	5-165		
10A-2	peat	0-58	till (CL)	58-165		
12B-1	peat	0-165				
12B-2	peat	0-165				
13C-1	peat	0-165				
13C-2	peat	0-165				
5B-1	peat	0-165				
5B-2	peat	0-165				

* Abbreviations in brackets are: Si - silt, C - clay, L - loam, S - sand

6. STUDIES OF ENVIRONMENTAL EFFECTS OF DISTURBANCES IN THE SUBARCTIC (SEEDS)

Agency Responsible

Department of Geography, University of Alberta

Funding Agency

Canadian Forestry Service, Northern Forest Research Centre
Department of Agriculture

Start-Up Date

May 1984.

Objectives

In an appropriate subarctic forest stand:

1. conduct a detailed monitoring of controlled experimental studies designed to manipulate disturbances that are themselves a simulation of a transport corridor in a subarctic forest ecosystem;

2. test, under controlled field conditions, several rehabilitation/ revegetation treatments to determine their relative merits; and,

3. develop a preliminary computer model that simulates the site conditions (Subarctic Environment Response Model - SERM) and test it with the data collected over the duration of the project.

Location

The research site is located north of Fort Norman and east of Bear Rock (Figure 6.1).

Results to Date

The study site is an homogeneous terrain/vegetation unit with ice-rich fine-grained soil on a gentle slope. The vegetation cover consists of a decadent (>200 yrs.) black spruce stand with feathermoss/Cladonia lichen ground cover.

A 690 m long simulated right-of-way (25 m wide) has been hand cleared. Along the right-of-way a 553 m long trench 2 m wide has been excavated and half of its length infilled with insulating organic material prior to backfilling.

The biotic and abiotic environmental characteristics are being described in detail on undisturbed (control), trenched, and cleared areas. An ecosystem approach is being taken and a number of separate studies have been designed to assess the various components (Table 6.1).

At the SEEDS site, a 25 m wide corridor was created over a 2 year period (Figure 6.2). The north-south oriented corridors were identified as ROW 1, 2, and 3 from west to east. In ROW 1, a complete trench was created, including the east-west link. ROWs 1 and 3 were completed in 1985 and ROW 2 was installed in 1986 with its trench. Within the trench, alternating 50 m stretches were backfilled with slash prior to the soil backfilling operation (Table 6.2). The slash was intended to act as a biodegradable insulative material. Trenching was done to the base of the active layer, an average of 50.7 cm (n=129, SD=14.6) and the organic surface layer,

including the moss and lichen layer, was mixed back with the mineral soil.

A number of surface test treatments were installed. They included combinations of seeding with agronomic or native species mixes or shrub whip plantings, and insulating or not insulating (Table 6.2). Seven of these species were agronomics that were also used in the nearby Norman Wells Project while the remainder were locally collected ecotypes. (Table 6.2).

Ecosystem Description

1. Abiotic

Microclimate

A network of automated dataloggers was established within the study area. It consisted of control, cleared right-of-way, and trenched areas with six, one, and nine sites with soil/permafrost and atmosphere parameters being sensed (Table 6.3). Soil/permafrost climate sensors were employed to log temperature data to a maximum of 225 cm with as many as six sensors positioned at various depths. There were a number of sensor depths that were common to all sites (0, 10, 50, and 200 cm below the moss surface).

Soil/substrate

Predisturbance soil sampling was conducted at 5 m intervals along the simulated pipeline trench (Figure 6.2). These studies were initiated in 1985 with the collection of over 380 samples from 49 soil pits (Evans and Kershaw, 1986). A further 300 samples were removed in 1986 and all these collections are currently undergoing laboratory analyses for moisture content, organic matter content, texture, and macronutrient content. A set of soil temperature sensors were

installed in 1984 (Table 6.3) and data on temperature profiles are currently being collected on a 12 month basis by automated dataloggers.

Permafrost

Permafrost studies rely on four sources of data:

a. Seventy cores extending 1.5 to 2.25 m below the moss surface were sunk to install thermocouple strings, frost tubes, and bedstead benchmark posts (Figure 6.2). Material removed during this network installation will be analyzed in the lab to provide quantification of ice contents and texture with a resolution of from 5 to 15 cm layers (coring depths between sample removal) (Kershaw and Evans, 1986);

b. Microclimate instruments and associated thermocouple network data are collected continuously from disturbed, reclamation test treatments and undisturbed sites from depths down to 2 m below the permafrost table (Table 6.3);

c. Frost tubes have been inserted in certain core holes (Figure 6.2). Approximately 30 will eventually be installed and monitored;

d. Weekly thaw depth surveys are conducted along transects that extend through the cleared rights-of-way from undisturbed forest (Figure 6.2). This will be extended to include a larger portion of the study area.

Topography

Topographic surveys have been initiated to quantify the subsidence occurring as a result of thermokarst processes. Intermediate scale surface topography was surveyed throughout the cleared rights-of-way and mesoscale topographic maps will be produced to spatially define the situation at the time of clearing. This will serve to illustrate

drainage systems during spring runoff and to define the scale of subsidence associated with the simulated pipeline trench.

As resolution provided by mesoscale mapping is inadequate to record microscale relief changes, a number of bedstead measurement sites were installed to quantify these topographic changes. This will enable measurement of extent and magnitude of heave, subsidence, and rill erosion.

Over the next few years, any surface elevation changes resulting from either thermal erosion or thermal subsidence will be quantified. A resolution of 1 mm is anticipated for these microscale measurements.

Hydrology

Surface runoff is restricted to the snowmelt period and the rare event of torrential rainfall. During the thaw season, a system of gauges will be installed to monitor discharges. Tracer dye may be used to determine residency time and source of runoff.

Subsurface flow within the active layer will be monitored during the thaw season to provide data to evaluate the extent of soil heat flux associated with soil water.

2. Biotic

Litter Fall

Litter traps were installed flush with the moss surface within the undisturbed area and ROW 3. A fine nylon mesh filter lined the traps to collect organic matter. Trays were emptied on a monthly basis during the snowfree period and the contents weighed and separated into components based upon species.

Litter decomposition

Nylon packets containing litter were deployed within undisturbed and disturbed areas to determine the rate of decomposition for 11 different types of litter. Included were leaf material only from the dominant evergreen shrub - labrador tea (Ledum groenlandicum); 3 deciduous shrubs - bearberry and 2 willows (Arctostaphylos rubra, Salix arbusculoides, and S. myrtillifolia); evergreen tree - black spruce (Picea mariana); a grass (Arctagrostis latifolia); and a sedge (Carex membranacea). Sixty-five sites were selected in each of the control area and ROW 1 (i.e. 130 sites in total) (Table 6.3). In addition, 100 filter paper packets were also deployed.

Vegetation

A base set of quadrats was selected randomly in the control area and ROW 1 (Figure 6.3). These sites were roughly surveyed and permanently marked for resurvey. Approximately half of the 60 quadrats were phenology plots and the other half were biomass plots harvested in 1985 or 1986. Floristics and cover within each of these plots was described.

Floristics

Quadrats randomly selected for phenology and biomass studies on the site were inventoried for species composition. A voucher collection of all species of vascular and nonvascular plants was made and a flora list was compiled for each quadrat.

Plant Cover

A visual estimate of cover was made for each plant species in the sample quadrats. All vascular and nonvascular plant species were

included in this analysis.

Plant Phenology

Plant phenotypic states were monitored throughout the growing season within 38 ROW 1 and 30 control quadrats (Figure 6.3). Fourteen and 20 surveys were completed in 1985 and 1986 respectively. Vegetative and reproductive phenophases were categorized and the first occurrence of each was noted. The quadrats are permanent and therefore year to year variations in phenotypic states can be compared for each species on a quadrat as well as a study basis.

Plant Vigour

Two evergreen shrubs labrador tea and crowberry (Ledum groenlandicum and Empetrum nigrum); 4 deciduous shrubs 2 willows, bearberry, and blueberry (Salix myrtillifolia, S. arbusculoides, Arctostaphylos rubra, and Vaccinium uliginosum); 2 sedges (Carex membranacea and C. vaginata); and a grass (Arctagrostis latifolia) were selected for analysis of vigor. These 11 species form the dominant understory cover and biomass of the vascular plants. Each specimen was divided into component parts and these were measured to determine dimensions (leaf width, length of underground shoots, etc.) (Figure 6.3).

Resprouting

To determine the nature and amount of resprouting from the root mass following a clearing operation, 150 Salix arbusculoides were randomly selected and denuded to ground level prior to clear cutting ROW 2. S. arbusculoides was the dominant erect shrub and the only species present in large enough numbers to be sampled in this fashion. All above ground portions were separated into the same categories as the

erect shrubs in the vigor studies. At the end of each growing season, beginning in 1986, 30 of these permanently marked specimens will be removed and root crowns excavated to determine minimum age estimates.

Phytomass

Within the undisturbed area and the cleared right-of-way, all vascular plant matter (above ground living tissue) below 150 cm height was cleared from selected plots (Figure 6.3). All material was then divided according to species into living and dead components; tree discs were removed for age determinations and cones counted according to the year of their formation.

Propagules

Both on-site and off-site sources of propagules are important to revegetation of disturbed terrain. Core samples of on-site propagules were removed, maintained in a moistened condition in a greenhouse, and monitored for sprouting. Off-site propagules were analyzed by transects and litter-fall traps. Three snow sampling transects are surveyed three times annually. All seeds are filtered out of the meltwater produced from the snow cores.

Herbivory

a. Insects

A pilot study was initiated to determine the suitability of pitfall traps in assessing insect populations and species diversity. Traps were checked every 14 days and collections retained to verify field identifications.

b. Mammals

Fourteen small mammal traplines containing ten traps each were installed across ROW 3 (Figure 6.4) prior to its clearing and monitored during and immediately following the clearing operations. These lines were run during two periods in 1985 and three periods in 1986. In 1986, the traplines were doubled in length and number of traps to include ROW 2. All animals were weighed and marked for recapturing. Distribution and composition data were collected and, in conjunction with these studies, exclosures to prevent foraging activities were installed to determine the impact of small mammal use of vegetation in the trench area. A set of exclosures will be removed each year and biomass clipping conducted to determine differences between excluded and open foraging areas.

Conclusions and Recommendations

Based upon a partial analysis of data collected over the first two years of the study, the following conclusions can be drawn:

1. The year to year variations in abiotic and biotic ecosystem components can be substantial.

2. Two years of data are insufficient to accurately describe changes in ecosystem components. It appears that a minimum of five years data will be necessary to provide a reliable, short-term, quantitative description of ecosystem processes in the subarctic.

3. Internal characteristics of such "fixed" ecosystem components as soils and permafrost are extremely variable and require large sample sizes at a high density to form reliable characterizations.

Future Studies

Due to budget uncertainty and constraints as well as a lack of personnel, only a skeleton monitoring programme will be conducted. It will consist of fewer sampling periods and fewer studies.

Reports Available

de Grosbois, T., G.P. Kershaw, L.J. Kershaw, and J.R. Eyton. 1987. The effects of canopy removal on the vigor of Salix arbusculoides Anderss. in a decadent Subarctic black spruce forest, Fort Norman, N.W.T. Unpublished SEEDS report, University of Alberta, Edmonton. 16pp.

de Grosbois, T., G.P. Kershaw, L.J. Kershaw, and J.R. Eyton. 1987. The effects of canopy removal on the vigor of Salix arbusculoides Anderss. in a decadent Subarctic black spruce forest, Fort Norman, N.W.T. Abstracts of the 16th. Arctic Workshop, Edmonton, Alberta, p.15-17.

de Grosbois, T., G.P. Kershaw, L.J. Kershaw, and J.R. Eyton. 1987. Spatial variation in the effects of canopy removal on the vigor of Salix arbusculoides Anderss. in a decadent Subarctic black spruce forest, Fort Norman, N.W.T. Canadian Association of Geographers, Western Division, Annual Meeting, Burnaby, B.C. p.20.

Evans, K.E., B.J. Gallinger and G.P. Kershaw. 1987. Soils and active layer characteristics in a Picea mariana stand, Fort Norman, N.W.T. Abstracts of the 16th. Arctic Workshop, Edmonton, Alberta, p.30-32.

Evans, K.E., B.J. Gallinger and G.P. Kershaw. 1987. Thaw depth and permafrost characteristics in a homogeneous Picea mariana stand, Fort Norman, N.W.T. Canadian Association of Geographers, Western Division, Annual Meeting, Burnaby, B.C., p.23.

Evans, K.E., and G.P. Kershaw. 1986. Soil and permafrost characteristics in a decadent black spruce stand, Fort Norman, N.W.T. Canadian Association of Geographers, Western Division, Annual Meeting, Edmonton, Alberta. p.18-19.

Evans, K.E., G.P. Kershaw, and B.J. Gallinger. 1988. Impacts of controlled surface disturbances on active layer and near surface permafrost in an homogeneous Picea mariana stand, Fort Norman, N.W.T., Canada. Fifth International Conference on Permafrost, Trondheim (in press).

Gallinger, B.J. and G.P. Kershaw. 1987. Regrowth performance of Salix arbusculoides Anderss. in a disturbed Subarctic forest ecosystem. Canadian Association of Geographers, Western Division, Annual Meeting, Burnaby, B.C. p.26.

Gallinger, B.J, K.E. Evans and G.P. Kershaw. 1988. Response of the active layer to human induced surface modifications, Fort Norman, N.W.T. Canadian Association of Geographers, Western Division, Annual Meeting, Castlegar (in press).

Kershaw, G.P. 1986. An overview of controlled experiment studies on simulated disturbances in a decadent black spruce stand, Fort Norman, N.W.T. Canadian Association of Geographers, Western Division, Annual Meeting, Edmonton, Alberta, p.24-25.

Kershaw, G.P. 1986. Ecosystem studies in the testing of rehabilitation treatments. Knowing the North, integrating tradition, technology and science. The Boreal Institute for Northern Studies, Edmonton. p.36.

Kershaw, G.P. 1986. Simulated disturbances and their use in the Reclamation of Subarctic Human Disturbances. Restoration and Vegetation Succession in Circumpolar Lands. Seventh conference of Comite Arctique International, Reykjavik, Iceland, p.23.

Kershaw, G.P. 1986. Studies of the Environmental Effects of Disturbances in the Subarctic, (S.E.E.D.S.), Year End Report 1985-86. Report submitted to Environment Canada, Canadian Forestry Service, Edmonton, 23pp.

Kershaw, G.P. 1987. Studies of the Environmental Effects of Disturbance in the Subarctic. Norman Wells Research and Monitoring Program, Fourth Annual Summary Report. Environmental Protection Service, Yellowknife, p.62-80.

Kershaw, G.P. 1987. Year-End Report 1986-87, Studies of the Environmental Effects of Disturbances in the Subarctic, S.E.E.D.S. Department of Geography, University of Alberta, Edmonton, 45pp.

Kershaw, G.P. 1988. The use of controlled surface disturbances in the testing of reclamation treatments in the Subarctic. In Northern Environmental Disturbances: Mitigation and Reclamation, Proceedings of a Workshop, 25th. Anniversary Conference, Knowing the North, Integrating Tradition, Science and Technology. G.P. Kershaw, (ed.) The Boreal Institute for Northern Studies, University of Alberta, Edmonton. (in press).

Kershaw, G.P., T. deGrosbois, K. Evans, L. Maslen, F. Reintjes, and I. Shukster. 1988. Microclimate characteristics of a Subarctic disturbance, Fort Norman, N.W.T. Canadian Association of Geographers, Western Division, Annual Meeting, Castlegar (in press).

Kershaw, G.P., T. deGrosbois, G. Demeriez, K. Evans, B. Gallinger, L. Maslen, F. Reintjes, and I. Shukster. 1988. Some microclimatic characteristics of surface disturbances in decadent Subarctic forests, Fort Norman, N.W.T., Canada. 17th. Arctic Workshop, Institute of Arctic and Alpine Research, Boulder (in press).

Kershaw G.P., and K.E. Evans. 1987. Soil and near-surface permafrost characteristics in a decadent black spruce stand near Fort Norman, N.W.T. B.C. Geographical Series No. 44:151-166.

Kershaw, G.P., and M. Fairbarns. 1985. Year-End Report, 1984 85, Studies of the Environmental Effects of Disturbances in the Subarctic (S.E.E.D.S.) (NOGAP Contract No.01K45-6-0202/1 SG) Department of Geography, University of Alberta, Edmonton. 82pp.

Kershaw G.P., B.J. Gallinger and L.J. Kershaw. 1987. Regrowth performance of Salix arbusculoides Anderss. following clearing in a Subarctic forest ecosystem. Abstracts of the 16th. Arctic Workshop, Edmonton, Alberta. p.66-68.

Kershaw G.P., B.J. Gallinger and L.J. Kershaw. 1988. Salix arbusculoides Anderss. responses to denuding and implications for northern rights-of-way. Fifth International Conference on Permafrost, Trondheim (in press).

Kershaw G.P., and L.J. Kershaw. 1987. A preliminary site description of the SEEDS study area with emphasis on the vegetation. Abstracts of the 16th. Arctic Workshop, Edmonton, Alberta. p.73-76.

Legris, A. manuscript. Effects of clearing activities associated with a pipeline right-of-way simulation on the vole population of a Subarctic black spruce forest. Canadian Field Naturalist.

Maslen, L. and G.P. Kershaw. 1987. The use of native shrub species in northern revegetation programs, Fort Norman, N.W.T. Abstracts of the 16th Arctic Workshop, Edmonton, Alberta. p.96-99.

Maslen, L. and G.P. Kershaw. 1987. The use of native shrub species in northern pipeline revegetation programs, Fort Norman, N.W.T. Canadian Association of Geographers, Western Division, Annual Meeting, Burnaby, B.C. p.32.

Maslen, L. 1987. Changes in Small Mammal Populations Following the Installation of A Simulated Transport Corridor in a Subarctic Black Spruce Forest. Unpublished SEEDS report, University of Alberta, Edmonton. 34pp.

Schmid, G. 1987. Gelandepraktikum in der kanadischen Subarktis, Fort Norman, Nordwestterritories. Marburger Geographische Gesellschaft e. V. 15:101-104.

Schotte, D.A. and G.P. Kershaw. 1987. Characteristics of tree biomass and its distribution in a decadent Picea mariana dominated stand, Fort Norman, N.W.T. Canadian Association of Geographers, Western Division, Annual Meeting, Burnaby, B.C. p.38.

Shukster, I.M. 1986. The effects of increased precipitation and decreased snow accumulation on earth hummocks, Fort Norman, Northwest Territories. 15th Arctic Workshop, Boulder. p.16.

Shukster, I.M. 1987. The Impact of Man-Induced Disturbances on Plant Phenology Stages in a Decadent Black Spruce Subarctic Forest, Fort Norman, Northwest Territories: Second Year Results. Unpublished SEEDS report, University of Alberta, Edmonton. 39pp.

Shukster, I.M. 1987. The Impact of Man-Induced Disturbances on Plant Phenology Stages in a Decadent Black Spruce Subarctic Forest, Fort Norman, Northwest Territories: Second Year Results. Canadian Association of Geographers, Western Division, Annual Meeting, Burnaby, B.C.

Shukster, I.M. 1987. The Impact of Man-Induced Disturbances on Plant Phenology Stages in a Decadent Black Spruce Subarctic Forest, Fort Norman, Northwest Territories: Second Year Results. Abstracts of the 16th. Arctic Workshop, Edmonton, Alberta, p.118-119.

Contact

Mr. Steve Zoltai
Canadian Forestry Service
Northern Forest Research Centre
5320 122 St.
Edmonton, Alberta T6H 3S5
(403) 435-1304

Dr. G.P. Kershaw
Department of Geography
University of Alberta
Edmonton, Alberta T5G 2H4
(403) 432-4408 Office

Table 6.1 Components of the Studies of the Environmental Effects of Disturbances in the Subarctic (SEEDS) project, Fort Norman, N.W.T.

Ecosystem Components	Principal Investigators 1984-1986 (alphabetical order)
	ABIOTIC
Permafrost characteristics	
Active layer	K. Evans, B. Gallinger, I. Shukster
Near-surface permafrost	K. Evans, B. Gallinger, I. Shukster
Microclimate characteristics	
Atmosphere/boundary layer	T. deGrosbois, P. Kershaw
Soil/permafrost	K. Evans, B. Gallinger, P. Kershaw L. Maslen, K. Evans
Surface Hydrology	
Runoff characteristics	B. Gallinger
Soil characteristics	
Physical	K. Evans
Nutrient	K. Evans
Litter	
Litterfall	L. Kershaw, P. Kershaw L. Maslen, K. Evans
Decomposition	L. Kershaw, P. Kershaw L. Maslen, K. Evans
	BIOTIC
Vegetation	
Floristics	L. Kershaw
Community description	L. Kershaw
Phenology	J. Beckingham, I. Shukster
Productivity	L. Kershaw, P. Kershaw, D. Schotte
Phytomass	L. Kershaw, P. Kershaw, D. Schotte
Vigour/Plant physiology	T. deGrosbois, L. Kershaw, P. Kershaw
Herbivores	
Small mammals	A. Legris, L. Maslen
	DISTURBED ECOSYSTEM COMPONENTS
	ABIOTIC
same as above	
	BIOTIC
same as above	
Propagules	M. Fairbarns, P. Kershaw, L. Maslen
Revegetation	
Agronomics/fertilizer	K. Evans, P. Kershaw
Native species - seeds	L. Maslen
- shrub whips	L. Maslen
- resprouting	L. Maslen, B. Gallinger

Table 6.2 Plant species involved in test reclamation treatments on a simulated pipeline trench, SEEDS, 1985 86.

Species	Test Treatment Number										
	1I	2I	3	4	5I	6I	7I	8	9I	10	11
AGRONOMIC SEED											
Poa pratensis	x		x								
Festica ovina	x		x								
F. rubra	x		x								
Agropyron pauciflorum	x		x								
Alopecurus arundinaceus		x		x							
Phalaris arundinacea	x		x								
Phleum pratense	x		x								
NATIVE SEED											
Arctagrostis latifolia				x						x	
Carex membranacea				x						x	
Epilobium angustifolium					x						
Empetrum nigrum					x						
Betula glandulosa					x						
Arctostaphylos rubra					x						
Ledum groenlandicum					x						
NATIVE SHRUB WHIPS											
Betula glandulosa						xS	xS	xC	xC	xS	
Alnus crispa							xS	xS	xC	xC	xS
Vaccinium uliginosum						xS	xS	xC	xC	xS	
Potentilla fruticosa						xS	xS	xC	xC	xS	
Salix arbusculoides						xS	xS	xC	xC	xS	
S. glauca						xS	xS	xC	xC	xS	

I: insulated with biodegradable material
C: control collections
S: seismic line collections

Table 6.3 Key ecosystem components measured in the Subarctic *Picea mariana* stand that was the focus of SEEDS

Components	Control	Right-of-way	Trench Reclamation Treatments 1I	2I	3	4	5I	6I	7I	8	9I	10	11
			(number of replicates)										
			ABIOTIC										
Atmospheric microclimate													
sensible heat													
+150 cm	2	1					2						
+ 50 cm	1	1					2						
+ 10 cm	2	1					2						
0 cm	6	1											
relative humidity													
+150 cm	1	1					2						
+ 50 cm							1						
+ 10 cm	1	1					2						
net radiation													
+150 cm	1						1						
global radiation													
+150 cm	1	1											
wind speed													
+300 cm	1	1					1						
+150 cm	1	1					1						
precipitation													
rain	1	1											
snow		1											
evapo-transpiration	2	6			1	1							
Soil/Substrate (Active Layer)													
temperature													
- 2.5 cm	1	1	1	1	1	1	1						
- 5 cm													
-10 cm	1	1	1	1	1	1	1						
-25 cm		1			1	1							
moisture content, texture, organic matter, nutrients	50 soil pits and 63+ cores sampled												
Permafrost													
temperature													
- 50 cm	1	1	1	1	1	1	1						
- 75 cm			1	1	1	1	1						
-100 cm				1			1						
-150 cm	1	1			1								
-200 cm	1	1	1	1	1	1	1						
-225 cm				1									
thaw depth progression (weekly)	123	156	15	15	15	15							
ice content	14	49	2	2	2	2							
texture	14	49	2	2	2	2							
Hydrology													
runoff	1	1				1							
through-flow	1	1				1							
Topography													
mesotopography), microtopography	topographic map encompassing the entire site												
	3	3			7	8							

I: insulated with biodegradable materials

Table 6.3 continued — Key ecosystem components measured in the Subarctic *Picea mariana* stand that was the focus of SEEDS

Components	Control	Right-of-way	Trench Reclamation Treatments 1I	2I	3	4	5I	6I	7I	8	9I	10	11
			(number of replicates)										
BIOTIC													
Litter fall													
litter decomposition	13	13											
Vegetation													
floristics	60	68	Not applicable										
cover	60	68	Not applicable										
phenology	30	38	Not applicable										
vigor	30	30	Not applicable										
phytomass	24/13	24/13	Not applicable										
productivity	24/13	24/13	Not applicable										
propagules	24	30	6										
Natural Revegetation													
floristics	NA	NA	To be conducted in 1987										
cover	NA	NA	To be conducted in 1987										
phenology	NA	NA	To be conducted in 1987										
vigour	NA	NA	To be conducted in 1987										
phytomass	NA	NA	To be conducted in 1987										
productivity	NA	NA	To be conducted in 1987										
propagules	24	30	To be conducted in 1987										
shrub resprouting	NA	30	To be conducted in 1987										
Assisted Revegetation													
floristics	NA	NA											
cover	NA	NA	60	60	60	60							
phenology	NA	NA											
vigour	NA	NA											
phytomass	NA	NA	NA	60	NA	60							
productivity	NA	NA											
seed viability)		for species used in seeding trials											
shrub whip planting	NA	NA											
Herbivory - Small Mammals													
abundance distribution		2520 trap nights covering 3 periods during snow-free season on entire site											

I: insulated with biodegradable materials
NA: not applicable

Figure 6.1 Location of the simulated disturbance installed for the project - Studies of the Environmental Effects of Disturbances in the Subarctic (SEEDS), Fort Norman N.W.T.

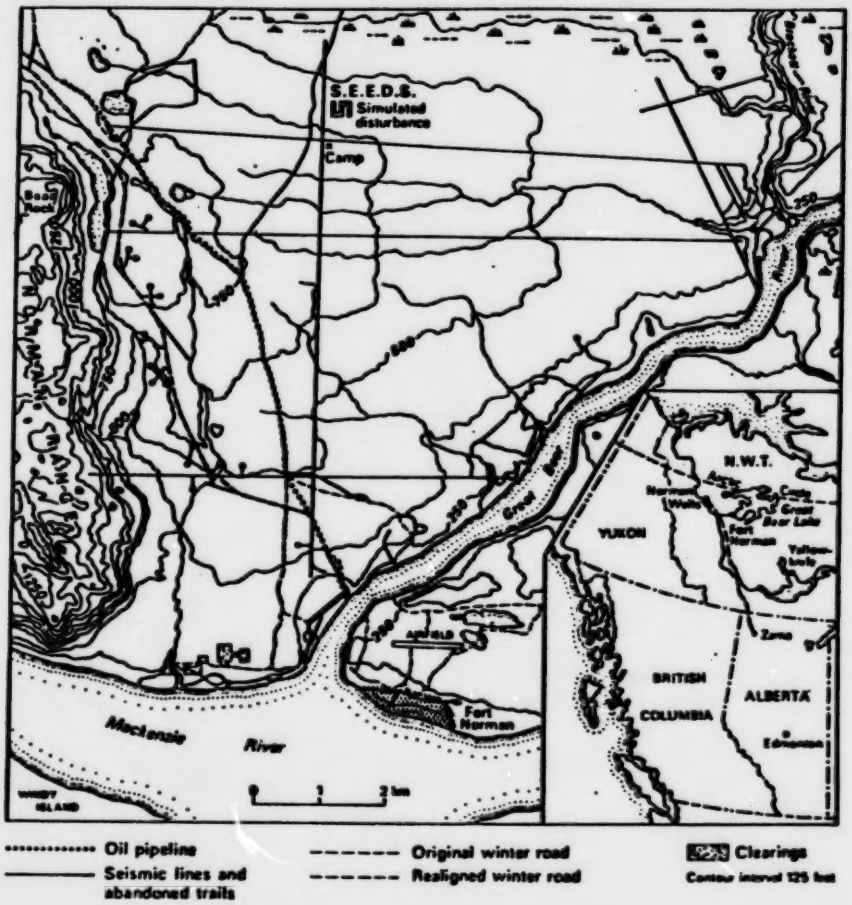


Figure 6.2 Abiotic baseline and monitoring networks.

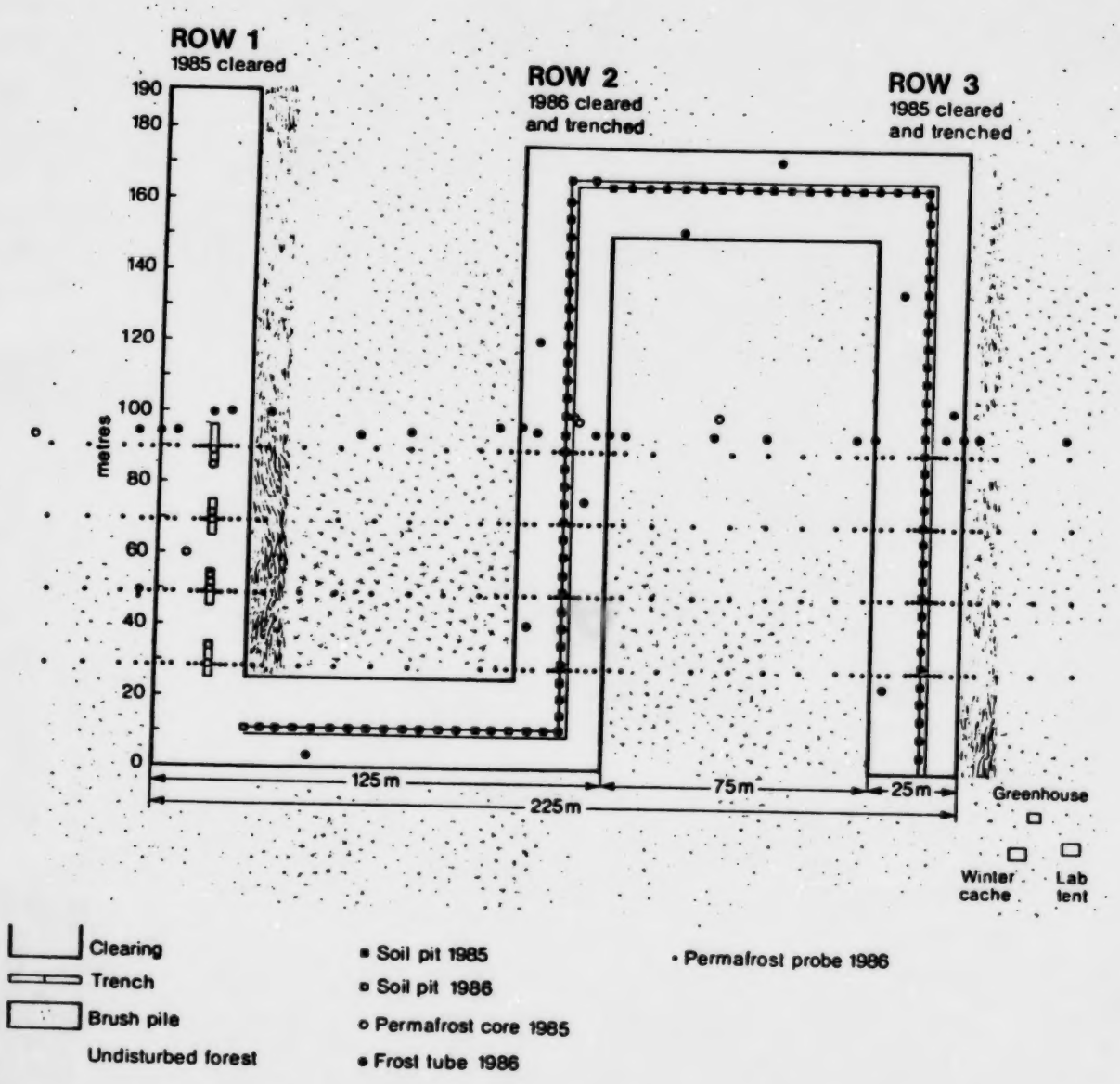


Figure 6.3 Biotic baseline and monitoring networks.

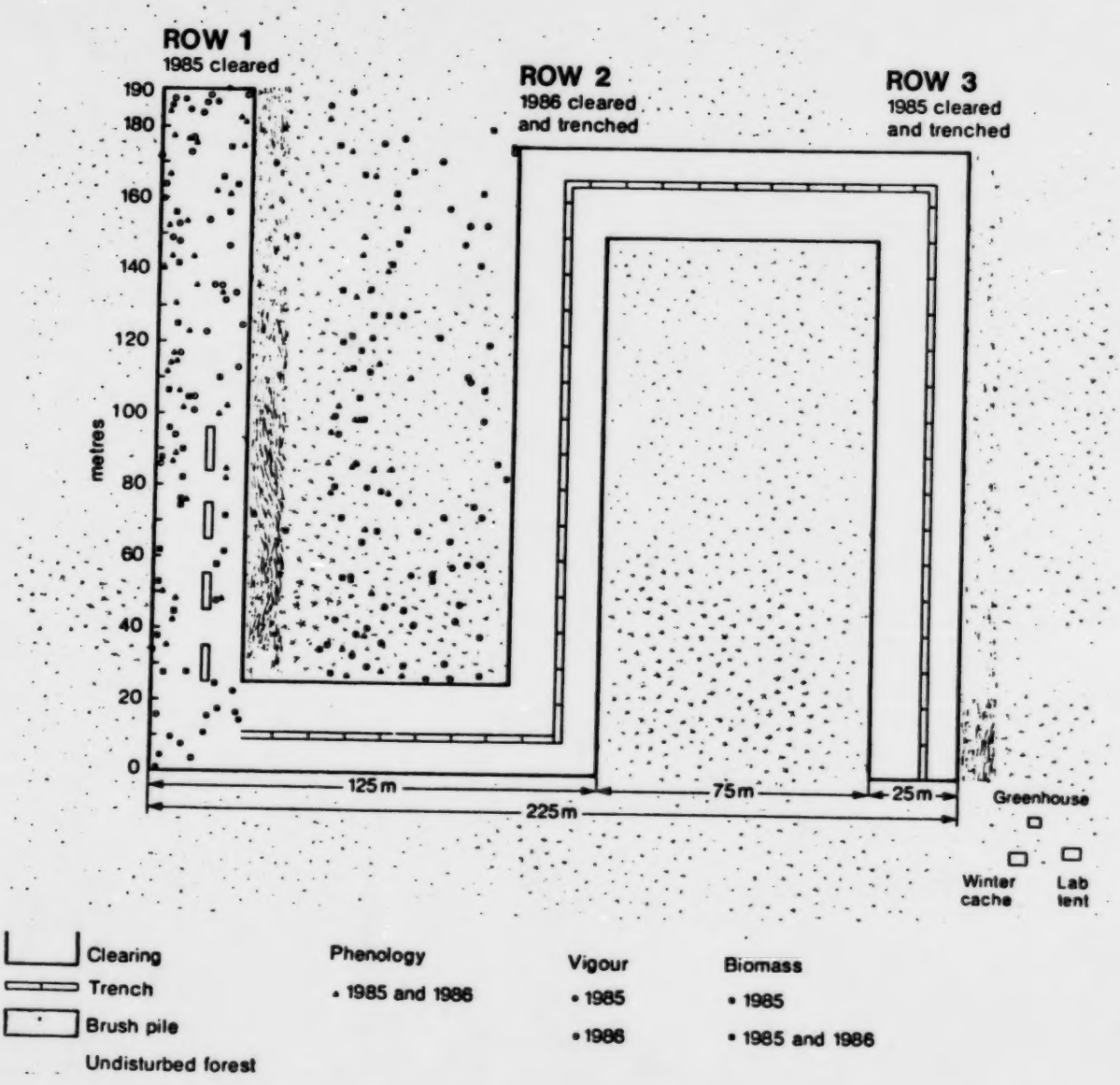
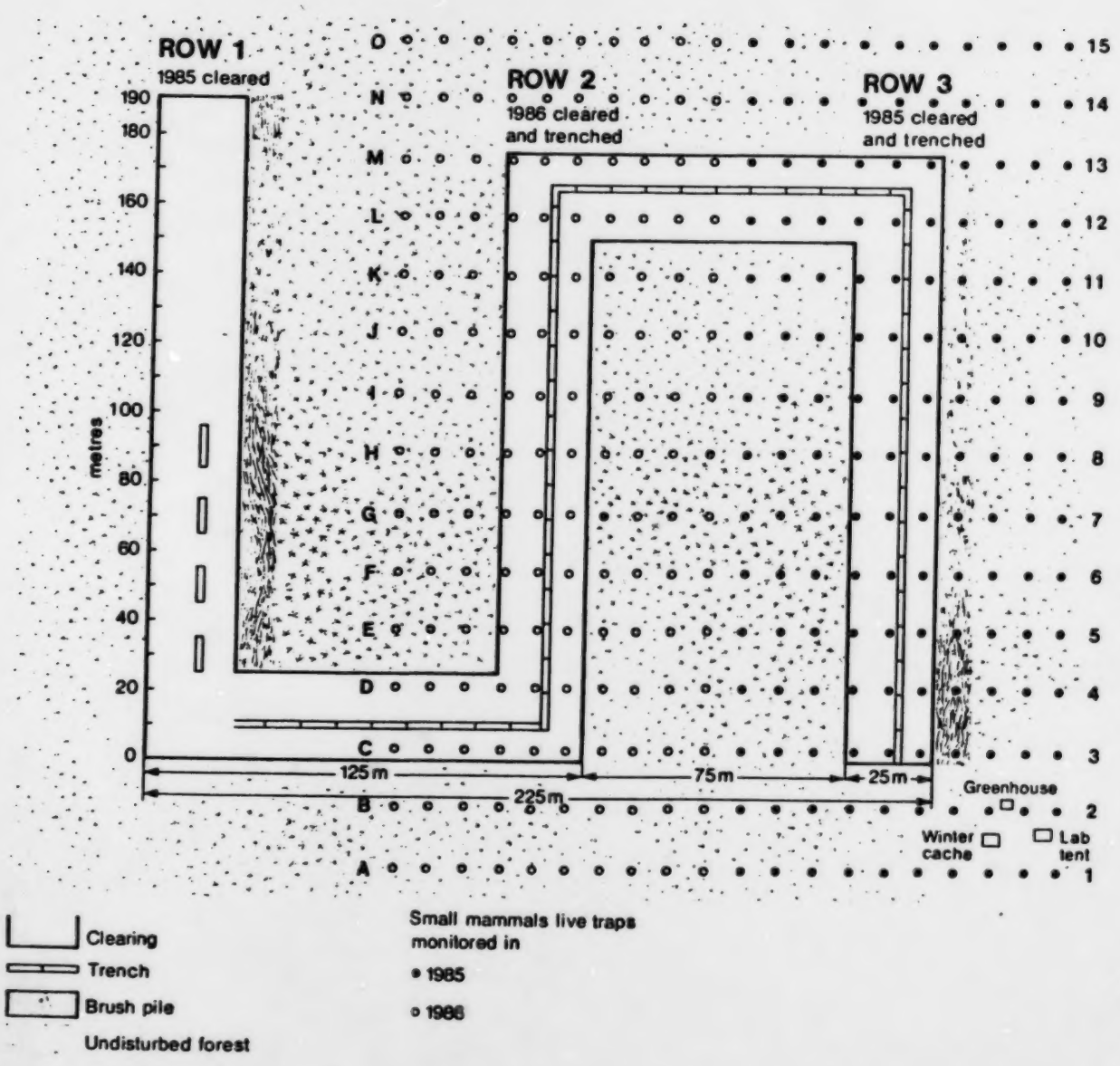


Figure 6.4 Approximate location of small mammal live trapping network



7. MACKENZIE RIVER CONTAMINANTS PATHWAYS

Agency Responsible

Environmental Protection, Environment Canada, Yellowknife, N.W.T.

Start-up Date

February, 1985

The following description and evaluation of the studies carried out from 1985 to 1987, and the conclusions and recommendations derived are taken from the summary report prepared by Steve E. Hrudey and Associates Ltd.

Objectives

Environmental Protection received funding for four years of studies, commencing in 1985, from the federal Northern Oil and Gas Action Program (NOGAP), with the overall objectives:

1. to provide the N.W.T. Water Board, Canadian Oil and Gas Lands Administration (COGLA) and Environment Canada with criteria for protecting aquatic resources from impacts from petroleum developments; and

2. to produce recommendations on the most effective methods for monitoring impacts on the Mackenzie River of contaminants released from petroleum developments.

Three phases of field and laboratory studies were conducted from the winter of 1984 to the spring of 1986. Part I was conducted from January to March 1985 by E.V.S. Consultants Ltd. This phase involved

a preliminary characterization of wastewater from the Norman Wells refinery, a literature review on the impacts, fate and behaviour of oil in freshwater ecosystems and a research program design.

Part II was conducted from the summer of 1985 to March 1986 by E.V.S. Consultants Ltd. This phase involved further characterization of refinery and oilfield development wastewaters, comparison of Norman Wells crude oil with natural seep oil and chemical characterization of Mackenzie River water, suspended sediments and bottom sediments. Field exposure experiments involving caged burbot and Arctic grayling were performed. Laboratory exposure experiments were also conducted using artificially weathered Norman Wells crude oil, wild burbot captured near Norman Wells and hatchery-raised rainbow trout.

Part III was conducted from September 1986 to April 1987 by E.S.L. Environmental Sciences Ltd. This phase involved a brief review of the Part I and II studies, statistical analysis of the caged burbot exposure experiment from Part II and brief literature reviews on the fate of contaminants in the Mackenzie River and on burbot ecology. Field work involved the collection of large volume composite samples of Mackenzie River water and suspended sediment upstream and downstream of the Norman Wells refinery in the fall of 1986 and again in the spring of 1987. As well, burbot were collected at several locations in the Normmber 1987 and these were subjected to a variety of qualitative and quantitative analyses.

In addition to the studies sponsored under this program, a series of companion studies addressing related issues were initiated by other agencies. The National Water Research Institute (NWRI) conducted surveys of water, suspended sediment and bottom sediment at a number of locations along the Mackenzie River during 1985 and 1986. The Department of Fisheries and Oceans (DFO) sent a set of burbot livers collected at Fort Good Hope to the University of Saskatchewan

(Dr. Wobeser) for pathological evaluation and also contracted with Arctic Biological Consultants to assess the degree of parasite infestation of burbot and whitefish. DFO also conducted extensive sampling and analyses of burbot and whitefish and limited sampling of northern pike, Arctic cisco and inconnu from several locations in the Northwest Territories and northern Manitoba. Finally, Esso Resources has collected routine monitoring data on the petroleum refinery and central processing facility effluents at Norman Wells as required by their Northwest Territories Water Board licences.

Results and Conclusions

The Part I and II studies have provided an excellent characterization of Norman Wells crude oil and natural seep oil which suggests that no substantial qualitative differences exist which would allow discrimination of petroleum contributions to the Mackenzie River. The river and source sample characterizations emphasize the importance of naphthalene and phenanthrene derivatives, rather than the higher molecular weight compounds like benzo(a)pyrene, as the major polynuclear aromatic hydrocarbons in this ecosystem. Hydrocarbon concentrations measured in the water and suspended sediments were extremely low. These findings were consistent with:

- tissue analyses which showed little evidence of the higher molecular weight hydrocarbons,
- bile fluorescence analyses which showed relatively low levels of fluorescence characteristic of benzo(a)pyrene-like metabolites, and
- histopathology analyses on burbot livers which showed an absence of malignant neoplasms.

Acute toxicity studies on Norman Wells crude oil and Norman Wells refinery effluent indicated that acute lethality in the Mackenzie River would not be expected.

The burbot liver problem was shown to have an objective basis, with some livers exhibiting small size and darkened colour relative to livers rated as desirable. Studies seeking a relationship of the burbot liver problem with hydrocarbon exposure did not demonstrate a statistically significant relationship and were inconclusive. A significant correlation between liver quality and liver lipid content was found in the Part III study. DFO studies have demonstrated that the burbot liver condition occurs at many locations in the Northwest Territories and northern Manitoba and that it can be experimentally induced by starvation. These findings suggest a relationship between this condition and the energy budget of the burbot.

A statistically significant correlation between benzo(a)pyrene-like fluorescence and hydrocarbon exposure was demonstrated for caged fish studies with Arctic grayling. However, no biological problems have been reported for grayling and no actual hydrocarbon exposure data were obtained with this experiment, making the importance of this preliminary finding uncertain.

DFO studies have found apparent widespread contamination of fish in the Mackenzie River with several organochlorine compounds but none of these analyses have been confirmed by mass spectrometry. Such compounds were not reported for crude oils, refinery effluents, river waters or sediments. However, the levels reported for fish were sufficiently low that, given their high bioconcentration factors, these compounds would be difficult to detect in the other media.

Overall, the studies completed to date have demonstrated the scope and scale of challenges which are associated with studying biological responses in a natural environment which is subjected to a wide variety of natural and anthropogenic influences.

Some deficiencies were noted relative to specific study objectives and more general requirements for assessing receiving water impacts. Effluent characterizations were limited in replication and followup. The importance of hydrocarbon contributions from licenced petroleum development discharges was not established relative to natural seeps, seepage from contaminated groundwater, or other sources. Existing models for plume dispersion and transverse mixing in rivers were not exploited in assessing likely river concentrations which could arise from known effluent sources. Overall, the hydrocarbon budget for the Mackenzie River ecosystem is essentially unknown because of a lack of baseline data on hydrocarbon distribution and a lack of assessments of fundamental processes, such as biodegradation, which influence that budget.

The technique of bile fluorescence monitoring focused on benzo(a)pyrene-like fluorescence despite data on the composition of Norman Wells crude and seep oils which indicated that phenanthrene or naphthalene-like fluorescence would be more relevant. Experiments have provided very little information about the uptake and elimination of hydrocarbons by locally important fish species. In addition, very little is known about the life cycle behaviour and basic biology of such fish; this makes it difficult to assess biological factors which may contribute to observed problems.

Recommendations

Measures to deal with perceived inadequacies in current knowledge were subdivided into monitoring and research requirements. Upgraded sampling and analysis of effluent discharges and chemical use by petroleum developments is proposed. A "paper" assessment of other contaminant contributions to the Mackenzie River and a qualitative reconnaissance survey of natural oil seeps are recommended to provide a basis for a contaminant budget. Continued water and suspended

sediment sampling will be needed to establish the contaminant budget.

Fisheries studies should focus on elaborating the basic biology of locally important fish species. These activities could benefit from an interview survey of long-standing fisherman throughout the region. Bile monitoring is given a lower priority, but is recommended for analysis of fish which are collected for other purposes. Emphasis in bile monitoring must be given to napthalene-like fluorescence. The findings of apparent widespread contamination of fish by organochlorine compounds should be verified by mass spectrometric analysis.

Research recommendations were developed by consideration of effluent and receiving environment issues. Specific research recommendations were limited to: evaluation of the solvent-filled dialysis bag technique for effluent monitoring, implementation of an available transverse mixing model for evaluation of licensed effluent plume discharges, once-only biodegradation studies to relate the Norman Wells circumstances to existing knowledge gained for other Arctic ecosystems, time course studies on uptake and elimination of petroleum contaminants by locally important fish species to provide a basis for assessing impacts of spill scenarios and consideration of future applications of advances in the use of sensitive biochemical indicators of fish response to petroleum contaminant exposure.

Future Studies

The 1987/88 Summary Report brings the four-year, NOGAP funded study to an end. The recommendations for future monitoring, research and impact control measures will be provided to government agencies and other regulators, such as the N.W.T. Water Board, as part of the ongoing responsibility of Environmental Protection to provide advice

on the regulation and monitoring of environmental impacts from petroleum developments.

Reports Available

ESL Environmental Sciences Limited. 1987. Assessment of Freshwater Impacts from the Norman Wells Oilfield Development. Part III. Prepared for Environmental Protection. N.W.T. District Office. Yellowknife, N.W.T.

EVS Consultants Ltd. 1985. Assessment of Freshwater Impacts from the Norman Wells Oilfield Development. Part I. Chemical Characterization of Produced Oil, Refinery Effluent, and Cooling Water. Literature Review of Fate and Effects. Research Program Design. Prepared for Environmental Protection, Yellowknife, N.W.T.

EVS Consultants Ltd. 1986. Assessment of Freshwater Impacts from the Norman Wells Oilfield Development. Part II. Field and Laboratory Studies. Prepared for Environmental Protection, Yellowknife, N.W.T.

Steve E. Hrudey and Associates Ltd. 1988. An Assessment of Freshwater Impacts from Petroleum Hydrocarbons on the Mackenzie River at Norman Wells, N.W.T. Part IV. Prepared for Environmental Protection, Yellowknife, N.W.T. Report CP(EP) WNR 87/88-5C.

Sutherland, D. 1984. A Discussion Paper on Water Quality Associated with the Norman Wells Oilfield Development. June 20, 1984.

Contact

Mr. Dave Sutherland
Environmental Protection
Department of the Environment
Box 370
Yellowknife, N.W.T. X1A 2N3
(403) 873-3456

Figure 7.1 Sample site locations in the Norman Wells study area.

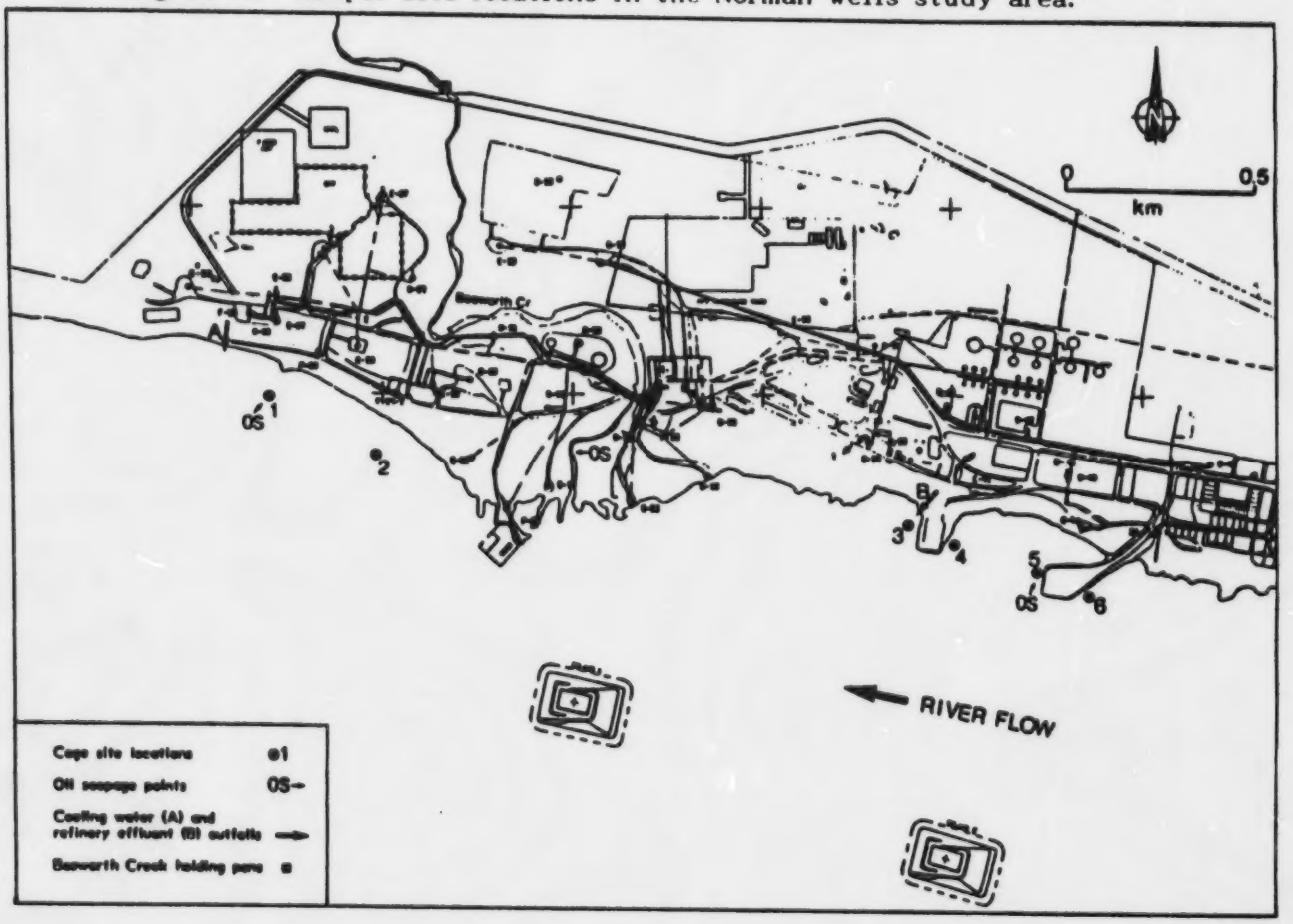


Table 7.1(a) Evaluation of burbot livers displayed at the Fort Good Hope Community Complex, October 1985

Site Number	Assessment of Livers Number Good	Number Bad	Percentage unacceptable response
1	0	26	100
2	5	21	81
3	5	21	81
4	21	5	19
5	14	12	46
6	25	1	4
7*	25	1	4

*Sucker Creek Control

Table 7.1(b) Evaluation of burbot livers by E.V.S. Consultants

Site Number	Assessment of Livers Number Good	Number Bad	Percentage Bad
1	4	2	33
2	4	2	33
3	3	3	50
4	5	1	17
5	4	2	33
6	6	0	0
7*	6	0	0

*Sucker Creek Control

Table 7.2 Levels of hydrocarbons found in Mackenzie River water, sediments and exposed fish at Norman Wells compared with liver acceptability test results

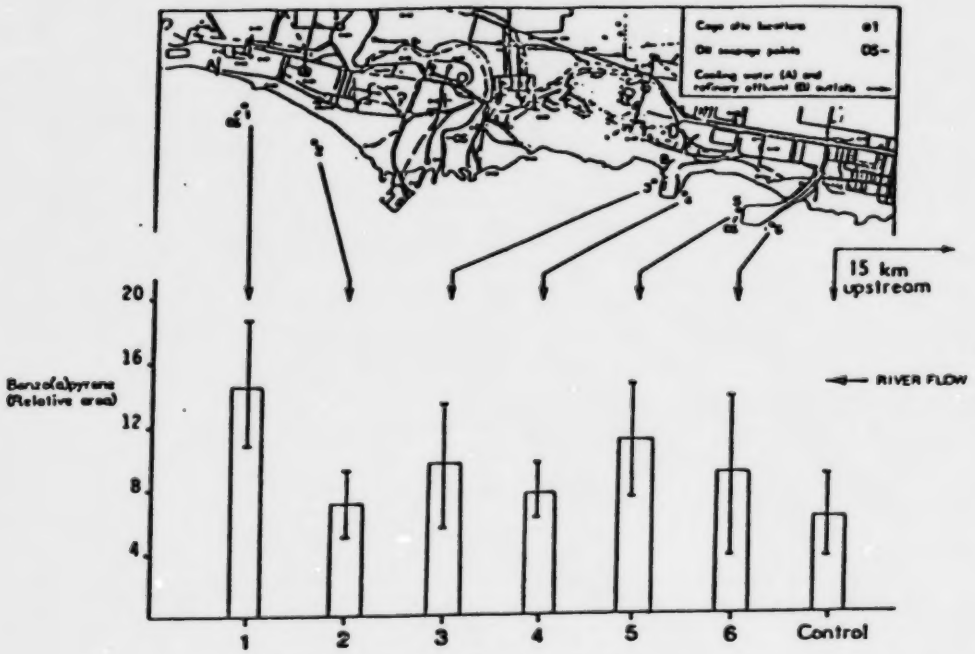
Site	Total Aliphatic Hydrocarbons as C-20			Burbot Bile Benzo(a)Pyrene (Relative Area)	Grayling Bile Benzo(a)Pyrene (Relative Area)	Grayling Bile Phenanthrene (Relative Area)	Burbot Liver Acceptability (Percentage unacceptable response)	Aromatic Hydrocarbons (Ethyl Benz; m,p-Xyl; o-Xyl)	
	Sediment (ug/dry gram)	Suspended Sediments (ug/g)	Surface Water (ug/L)	n $\bar{x} \pm$ S.E.	n $\bar{x} \pm$ S.E.	n $\bar{x} \pm$ S.E.		Burbot Liver (ppb) n mean total	Grayling Tissue (ppb) n mean total
Control	-		-	4 6.1 ± 2.6	5 21.2 ± 1.3	3 222.3 ± 37.2	4	2 2,423.1	3 618.8
1	3.7	13.0	L 10	5 14.4 ± 3.8	4 33.4 ± 6.2	2 461.5 ± 267.2	100		
2	18.0		L 10	5 7.1 ± 1.9	4 31.7 ± 8.6	2 510.0 ± 23.1	81		
3	12.0		L 10	3 9.3 ± 3.9	4 51.8 ± 2.3	2 682.5 ± 164.9	81	2 1,288.8	3 965.4
4	5.1		L 10	5 7.7 ± 1.7	4 33.9 ± 9.7	2 482.5 ± 103.8	19		
5	148.0		56.5	5 10.8 ± 3.6	4 52.0 ± 5.6	2 740.5 ± 25.6	46	2 1,405.7	3 514.5
6	5.3	9.8	L 10	5 8.8 ± 5.2	4 31.1 ± 2.9	2 329.0 ± 96.3	4		
Reference	-		-	-	10 107.1 ± 21.4	2 1,460.0 ± 30.1	-		3 1,119.1

n = number of fish sampled

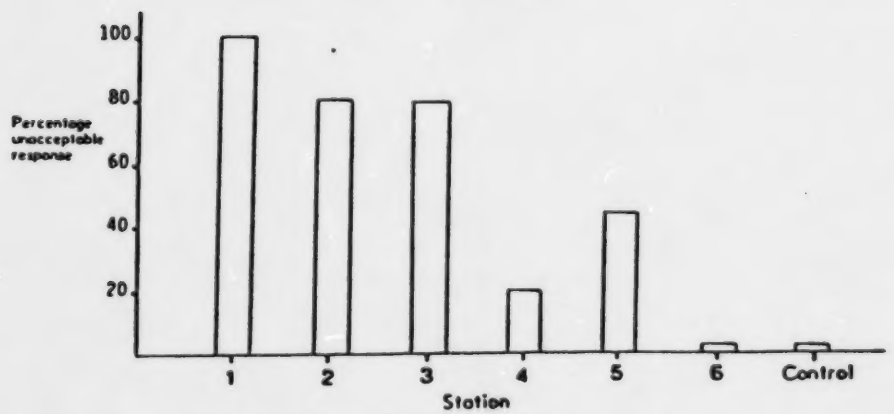
$\bar{x}$ = mean

S.E. = standard error = standard deviation/$\sqrt{n}$

Figure 7.2(a) PAH uptake by exposed burbot (mean and standard error) compared with liver acceptability test results.



(i) Benzo(a)pyrene in Burbot Bile



(ii) Liver Acceptobility Test Results

Figure 7.2(b) PAH uptake by exposed Arctic grayling (mean and standard error)

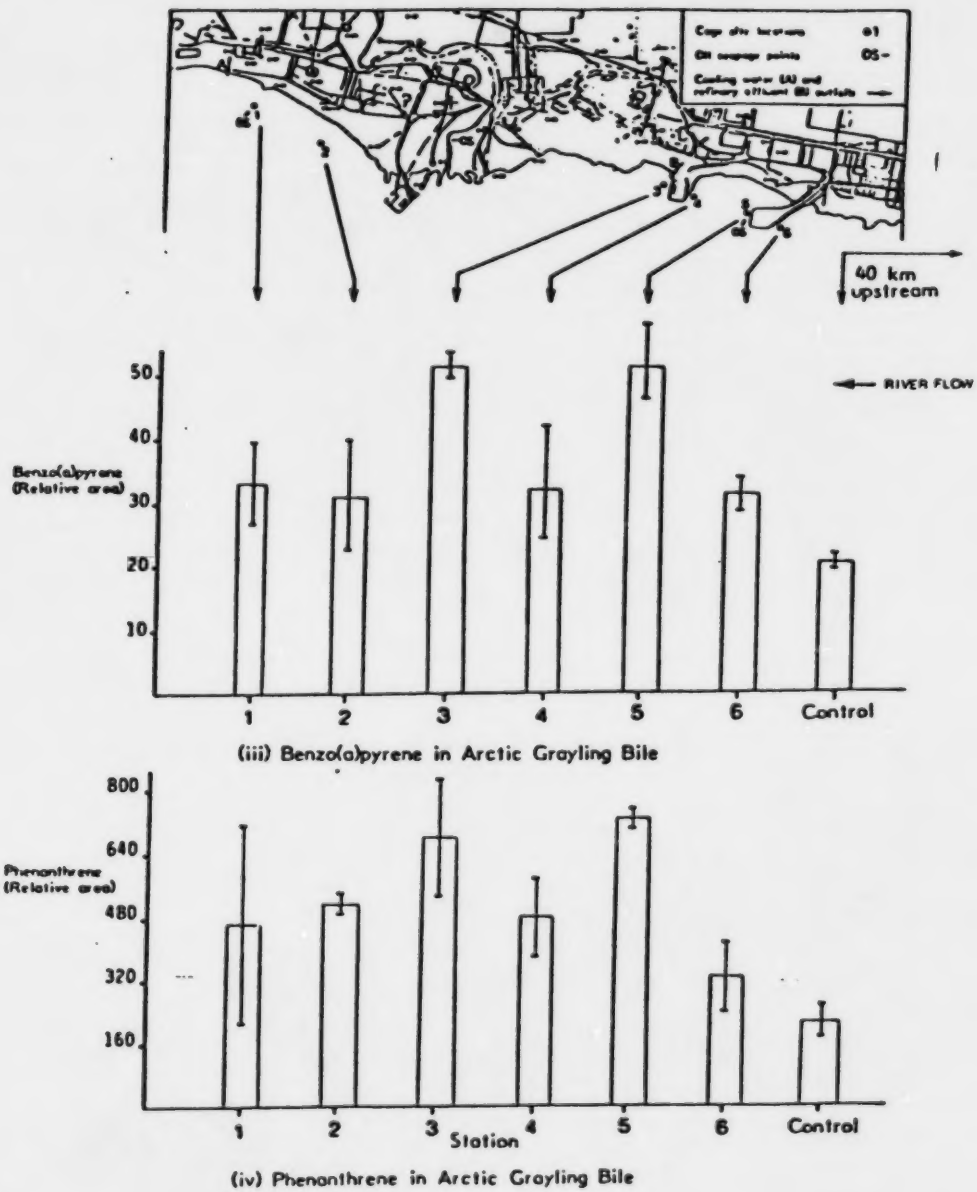


Table 7.3 Uptake of benzo(a)pyrene in bile of burbot, Arctic grayling and rainbow trout, and levels of aromatic hydrocarbons in dorsal muscle tissue of rainbow trout.

Sample	Exposure Medium	Exposure Time	Burbot Bile Benzo(a)Pyrene (Relative Area) n $\bar{x} \pm$ S.E.	Grayling Bile Benzo(a)Pyrene (Relative Area) n $\bar{x} \pm$ S.E.	Rainbow Trout Bile Benzo(a)Pyrene relative			Rainbow Trout Tissue Aromatic Hydrocarbons (Ethyl Benz; m,p-Xyl; o-Xyl)		
					n[a]	area	condition	n[a]	ppb	condition
Field control	River water upstream from Norman Wells	long term	4 6.1 ± 2.6	5 21.2 ± 1.3		-			-	
Lab control (oil bioassay)	Vancouver dechlorinated water	10 days	3 8.0 ± 2.1	-	1	6.6	open	1	417	open
Lab control (effluent bioassay)	Vancouver dechlorinated water	10 days	2 6.7 ± 0.4	-	1	6.8	closed	1	586	closed
Field reference	Norman Wells midstream river water	indefinite (fish age = 3 yrs)	-	10 107.1 ± 21.4		-			-	
Site 5 *in situ* exposure	Norman Wells river water adjacent to oil seep	10 days	5 10.8 ± 3.6	4 52.0 ± 5.6		-			-	
Laboratory oil bioassay (ambient)	5 ppm (v/v) weathered crude oil	10 days	3 41.1 ± 3.8	-	1 1	78.9 15.4	open closed		-	
Laboratory oil bioassay (threshold)	1000 ppm (v/v) weathered crude oil	10 days	3 86.8 ± 37.9	-	1	79.9 N.D.	open closed	1 1	669 1,213	open closed
Site 3 *in situ* exposure	Norman Wells river water in effluent plume	10 days	3 9.3 ± 3.9	4 51.8 ± 2.3		-			-	
Laboratory effluent bioassay	100 percent refinery effluent	10 days	3 83.9 ± 18.9	-	2 2	33.0 ± 6.9 26.8 ± 5.8	open closed	1 1	712 919	open closed

n = number of fish sampled

[a] = composite samples from 5 fish

$\bar{x}$ = mean

S.E. = standard error = standard deviation/$\sqrt{n}$

N.D. = not determined

8. MACKENZIE RIVER BASELINE MONITORING OF PETROLEUM HYDROCARBONS

Agency Responsible

Water Quality Branch, Inland Waters Directorate (IWD), with the cooperation of National Hydrology Research Institute, (NHRI) Saskatoon, and National Water Research Institute, (NWRI) Burlington.

Start-up Date

1985

Objectives

1. to develop methods for monitoring petroleum hydrocarbons in the water and sediment of the Mackenzie River, and

2. to establish a baseline of petroleum hydrocarbon and metal concentrations in water and sediment upstream and downstream of the Norman Wells oilfield development.

Locations

Eight sample sites were located from Fort Simpson to the Mackenzie Delta (Figure 8.1).

Results to Date

Results from the 1985 low flow survey indicated the presence of hydrocarbons originating from the Liard River system. An aerial reconnaissance survey resulted in the mapping of oil and gas development activities in the basin. Bottom sediment sampling was subsequently carried out on the NWT portion of the Liard River.

Hydrocarbon analysis of these sediments is being completed at the NWRI laboratory.

A second field survey for hydrocarbons and heavy metals was carried out on the Mackenzie River during June 1986 to describe ambient concentrations at high flow periods.

The first ambient hydrocarbon baseline data base is now being developed for the Mackenzie River. Preliminary results indicate:

1. Inputs of hydrocarbons to the Mackenzie River arise from a diversity of sources including natural seepages, long range transport phenomena, and the Liard River Basin.

2. The predominant hydrocarbon source in the Mackenzie River cannot be determined at this point. Further sampling is required to establish the contribution of all sources to the total hydrocarbon load in the Mackenzie River.

Utilization of Results

The data and knowledge obtained from the first two surveys of the Mackenzie River have improved our understanding of hydrocarbon characteristics in this system.

1. It is now clearly evident that suspended sediments constitute a major pathway for hydrocarbons moving through the aquatic system.

2. Much larger volumes of water (100 litres vs. 1-16 litres) must be sampled in order to identify the ambient levels of hydrocarbons in northern rivers with precision.

While energy demands fluctuate periodically, it is likely that

long term hydrocarbon development will occur in the Mackenzie Basin. These surveys are producing the scientific techniques required to monitor on going and future hydrocarbon developments. Moreover, they are establishing a data base for ambient levels of hydrocarbons in the Mackenzie River where none previously existed. This data base becomes especially valuable when combined with related NOGAP projects on the Mackenzie River. Based on a scientific monitoring program, it is now becoming possible to comment on the relative importance of Imperial Oil Limited's discharges versus naturally occurring seeps. It is also evident that the Liard Basin may constitute a significant source of hydrocarbons to the Mackenzie River.

Present and Future Studies

An under-ice survey in March 1988 at selected points from Fort Simpson to the Mackenzie Delta has been conducted to detect the presence of light aromatic petroleum hydrocarbons.

Sampling for three additional years through to 1990/91 will attempt to duplicate results to date with respect to suspended sediments, bottom sediments, and water column monitoring during high flow, low flow, and under ice conditions. (Funding for this three year program has yet to be confirmed.)

Reports Available

Environmental Protection Service and Inland Waters Directorate. 1985. NOGAP Project Description for: Criteria for the Control and Monitoring of Petroleum Development Impacts on the Mackenzie River. (includes Environmental Protection component of the study). January 1985.

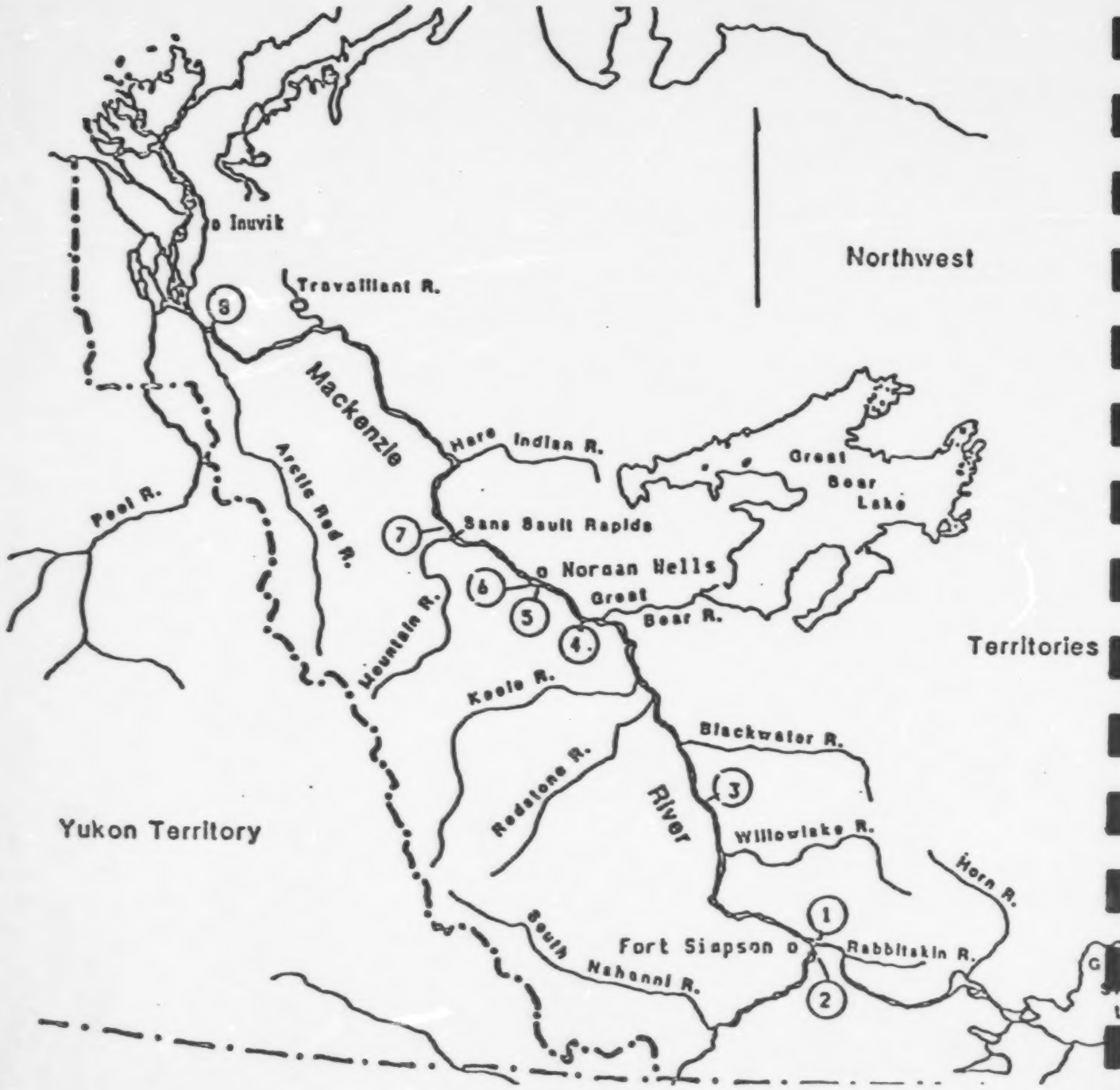
Nagy, E., J.H. Carey, J.H. Hart, E. Ongley, and J. Tisdale. 1986. Hydrocarbons in Mackenzie River Suspended Sediments. NWRI Contribution No. 86-65. Environment Canada.

Nagy, E., J.H. Carey, J.H. Hart, E. Ongley, and J. Tisdale. 1986. Hydrocarbons in Mackenzie River Water and Suspended Sediments: 1985 Low Flow and 1986 High Flow Surveys.

Contact

Mr. Brian Olding
Water Quality Branch
Inland Waters Directorate
Department of the Environment
P.O. Box 2970
Yellowknife, N.W.T. XIA 2R2
(403) 920-8516

Figure 8.1 Mackenzie River sampling sites 1985



9. FISH QUALITY AND PHYSIOLOGICAL CONDITION

Agencies Participating

Department of Fisheries and Oceans (DFO)
Department of Indian Affairs and Northern Development
Dene Nation

Start-up Date

October 1985

Objectives and Methods

To determine the causes of poor quality fish caught in the lower Mackenzie River by local fishermen, by:

1. collecting fish samples from several Mackenzie River locations to determine the incidence of poor quality fish in the domestic fishery; and

2. analyzing fish and their tissues to determine whether the abnormal conditions occur naturally or result from anthropogenic changes in the environment.

Locations

Arctic Red River, Fort Good Hope, Fort Franklin, and Fort Simpson

Results to Date

Fish from four locations were collected during October 1985 by Hatfield Consultants Ltd. under contract to the Dene Nation. An

attempt was made to obtain 20 each of whitefish and burbot from each of four locations (Arctic Red River, Fort Good Hope, Fort Simpson, and Fort Franklin), generally obtaining burbot with baited hooks and whitefish with gill nets. The intent in collecting this set of samples was to see whether the condition of the fish could be related to the geographic relationship of the collecting sites to a source of contamination at Norman Wells. Field conditions at the time of sampling precluded sampling directly in Great Bear Lake, and the Ft. Franklin samples had to be collected from a small lake near the community. The small lake had been used historically as a float plane base and may have experienced contamination with petroleum fuels, and so its value as a "control" may be limited.

Additional collections of fish relevant to the study were made by DFO staff at Fort Good Hope during November 1983, March 1984, April 1985 and September 1986, at Great Slave Lake in April 1985, at Lake Winnipeg in February 1986, and at Fort MacPherson in October 1986. A further collection of burbot was made by staff of the Government of the Northwest Territories at Fort Simpson in April 1986.

Most sample analyses have now been completed and it is concluded that:

1. The complaints about dark colour and small size of burbot liver are wide spread and the condition is prevalent in burbot from several communities both within and outside the Mackenzie River drainage. The appearance of the liver is linked to the energy stored in the liver, and the condition can be produced experimentally by reducing liver fats. The cause of the liver condition is unlikely to be exposure to petroleum hydrocarbons, although these cannot be ruled out conclusively. If the cause of the condition of burbot liver does include exposure to petroleum hydrocarbons, then clearly Norman Wells is not the exclusive source.

2. The most specific diagnostic test available, namely liver mixed-function oxidase enzymes, indicated that the northern burbot were not responding to oil pollution. However, this interpretation may have been complicated by the observation that the "control" population of burbot from Lake Winnipeg had higher levels of PCBs than the arctic burbot, and this could have elevated the controls and hence masked oil induction in the arctic fish.

3. The fish from all locations sampled were contaminated with low levels of low-boiling aromatic hydrocarbons typically present in Norman Wells crude oil and in refined petroleum products. The extent of this contamination indicated widespread occurrence of these compounds, however, the level of this contamination at Ft. Good Hope was several times higher in late winter than in late fall, which suggested an additional source of the hydrocarbons under river ice. The winter vs. summer difference was not evident at Ft. Simpson, which further suggested that an under-ice source might be located between Ft. Simpson and Ft. Good Hope.

4. Only anecdotal reports are available on the first appearance of the small dark livers in burbot. If it has indeed become prevalent only recently, then it is legitimate to search for recent changes in the environment that might offer some explanation. While sample sizes are very small, the limited data do not indicate a decrease in the growth rates of the fish taken in 1985 as compared with those in the early 1970's. Clearly, the liver condition is related to the liver content of fat and calories, and such a relationship suggests the likelihood of a linkage to growth. The absence of a change in growth rate then suggests that the liver condition may have been present, but not reported, for some time.

5. There is widespread contamination of fish from the Mackenzie River with low levels of several organochlorine compounds, notably toxaphene, chlordane, and PCBs.

6. The complaint regarding "watery" flesh of whitefish is legitimate in that the northern whitefish have higher water content and lower fat content than most other samples of whitefish for which data are available.

7. Conclusions from the parasite study data:
   A nematode larva, Raphidascaris acus, increased in intensity with increased liver atrophy in large burbot from the Mackenzie River. A similar increase was also noted for a cestode, Triaenophorus nodulosus plerocercoids, in burbot from Fort Franklin, N.W.T. The correlations that appeared to exist between liver atrophy in large burbot and the presence of these pathogenic larvae may be valid. However, it has not yet been determined whether parasite infestations resulted in liver atrophy or if in fact atrophied livers are more susceptible to infestation.

Future Studies

It has been recommended that:

1. additional studies be done to describe the extent of the contamination of northern fish with organochlorines, and to measure the rates of clearance from the fish.

2. in view of the higher concentrations of PCBs in the Lake Winnipeg burbot, induction-specific inhibitors be used to determine unambiguously whether arctic burbot are induced.

3. identification of alkanes be confirmed by more conclusive means, and that experimental uptake and clearance studies be done with burbot and known mixtures of odd and even numbered alkanes to determine whether the observed pattern of alkanes in the fish could have resulted from exposure to crude or refined petroleum.

4. sampling and analysis of bile for PAH metabolites be continued.

5. additional arctic river populations of burbot and whitefish outside the Mackenzie watershed be sampled for comparison.

6. experimental infection with the parasite R. acus be attempted to determine whether that infestation produced the dark small livers.

7. Health and Welfare Canada determine whether consumption of burbot liver might be hazardous in view of the contaminants present.

8. systematic survey work on burbot and whitefish biochemistry be continued to define the influences of habitat type, season, and biological variables (sex, age, etc.) on liver condition and body composition.

Studies planned for the balance of 1988 include collection of additional burbot from Lake Winnipeg for further laboratory induction studies with burbot exposed to oil, toxaphene, chlordane, PCB, and phenobarbital, examination of fish collected from the Churchill River drainage of northern Manitoba, and collection of another winter sample from Ft. Good Hope in March.

Reports Available

Bernier, L.M.J. 1986. Liver pathology of burbot Lota lota (Linnaeus) and the parasites Raphidascaris acus (Bloch) and Triaenophorus nodulosus (Pallas) with Notes on Transmission Routes.

Lockhart, W.L., D.A. Metner, D.A.J. Murray, B.N. Billeck, C.L. Baron, D.C.G. Muir and K. Chang-Kue. 1986. Studies to determine whether the condition of fish from the Lower Mackenzie River is related to hydrocarbon exposure. Unpublished data report. Department Fisheries and Oceans. 121pp.

Lockhart, W.L., D.A. Metner, D.A.J. Murray, R.W. Danell, B.N. Billeck, C.L. Baron, D.C.G. Muir and K. Chang Kue. 1987. Studies to determine whether the condition of fish from the Lower Mackenzie River is related to hydrocarbon exposure. Unpublished data report. Department Fisheries and Oceans. 179pp.

Contact

Mr. Jeff Stein

Resource Impact Division

Department of Fisheries and Oceans

501 University Crescent

Winnipeg, Manitoba R3T 2N6

(204) 949-5164

Table 9.1. Data summary for fish collected at Fort Good Hope, NWT. April 1985

Species	Sample No.	Fork Length (mm)	Weight (g)	Age (yr)	Maturity	Gonad Weight (g)	Liver Weight (g)	Liver % Body Weight	Condition Factor	Consumption Suitability	Histo-[1] pathology	Path-[2] ology
Burbot	4	923	4,450	16	female-spent	59	79	0.56	.5659	bad	0	-
	5	650	1,295	10	female-immature	3	27	2.08	.4716	medium	1	-
	6	602	1,305	7	female-immature	5	165	12.64	.5982	good	2	-
	9	562	1,117	8	male-immature	1	122	10.92	.6293	good	2	-
	10	595	1,030	8	male-resting	8	30	2.91	.4890	medium	2	-
	11	603	1,023	11	male-spent	22	31	3.05	.4666	medium	1	-
	12	553	728	10	male-resting	5	26	3.57	.4305	medium	2	-
	13	626	1,380	8	female-immature	5	57	4.13	.5625	good	2	-
	14	540	713	8	male-resting	4	17	2.38	.4528	bad	0	1
	15	754	2,050	14	male-spent	37	40	1.95	.4782	medium	-	-
	16	775	2,500	14	male-spent	32	128	5.12	.5371	medium	2	-
	17	702	1,600	11	male-spent	19	60	3.75	.4625	good	1-2	-
	18	645	1,454	7	male-resting	13	36	2.48	.5419	medium	1-2	-
	19	600	869	10	male-spent	8	23	2.65	.4023	medium	1	-
	23	860	3,750	15	female-resting	13	321	8.56	.5896	good bad	2	2
	24	625	1,500	11	female-resting	5	90	6.00	.6144	good	2	-
Lake Whitefish	2	383	770	14	female-resting	11	17	2.21	1.3705	-	3	-
	3	345	554	10	female-resting	5	-	-	1.3491	-	1-3	-
	8	345	577	10	female-immature	3	-	-	1.4051	-	-	-
	21	398	846	13	male-immature	1	-	-	1.3419	-	3	-
	22	310	346	8	female-immature	2	-	-	1.1614	-	3	-
	25	395	790	16	female-resting	2	-	-	1.2818	-	3	-
	26	346	598	10	male-immature	1	-	-	1.4437	-	1-3	-
Inconnu	7	860	8,550	15	female-mature	214	102	1.19	1.3442	-	3	-
	20	440	818	5	male-immature	1	-	-	.9603	-	3	-
Northern Pike	1	693	2,938	16	male-mature		85	2.89	.8828	-	2	-

[1] Histopathology: 0 - severe atrophy, low lipid content. 1 - mild to moderate atrophy, moderate lipid content; 2 - normal, lipid filled; 3 - actively regenerating/growing.

[2] Pathology: 1 - brown, pea-sized inclusions in liver; 2 - bacterial pathogen Yersinia ruckerii isolated.

Table 9.1 (continued) Data summary for fish collected at Fort Good Hope, NWT. April 1985

Species	Sample No.	Trace Metals in Liver (ug/G, wet wt.) Pb	Cu	Cd	Hg	Se	Zn	% moist	Trace Metals in Muscle (ug/G, wet wt.) Pb	Cu	Cd	Hg	Se	Zn	% moist	Liver Parasites Species[1]	#	Liver Color[2]
Burbot	4	<0.10	22.20	<0.10	0.25	1.02	34.30	79.30	<0.05	0.16	<0.01	0.48	0.29	5.32	82.70	R.A.	14	DB
	5	<0.10	25.50	0.28	0.19	2.19	33.10	59.40	<0.05	0.13	<0.01	0.50	0.48	2.94	81.60	-	-	-
	6	<0.10	1.60	<0.10	0.02	0.61	9.79	41.30	<0.05	0.22	<0.01	0.14	0.40	4.94	78.00	-	-	W
	9	<0.10	3.60	<0.10	0.01	1.47	10.80	45.30	<0.05	0.16	<0.01	0.22	0.59	3.39	79.40	-	-	W
	10	<0.10	16.60	0.19	0.04	1.37	30.70	57.10	<0.05	0.20	<0.01	0.16	0.39	5.94	81.00	-	-	W-PB
	11	<0.10	30.10	0.17	0.07	1.94	54.30	69.60	<0.05	0.18	<0.01	0.22	0.33	5.19	82.30	R.A.	1	W-PB
	12	<0.10	23.00	0.25	0.04	1.96	34.80	62.80	<0.05	0.31	<0.01	0.19	0.34	5.94	81.70	-	-	PB
	13	<0.10	4.90	0.25	0.05	2.07	15.30	43.30	<0.05	0.14	<0.01	0.30	0.60	3.70	81.20	-	-	W
	14	-	-	-	-	-	-	-	<0.05	0.28	<0.01	0.21	0.34	5.81	83.60	R.A.	1	DB
	15	<0.10	34.10	0.35	0.07	2.87	51.60	65.00	<0.05	0.15	<0.01	0.27	0.28	4.69	82.30	R.A.	1	PB
	16	<0.10	8.60	0.11	0.03	0.82	20.10	47.90	<0.05	0.18	<0.01	0.23	0.31	4.42	81.20	-	-	PB
	17	<0.10	18.00	0.38	0.04	1.69	37.40	58.30	<0.05	0.26	<0.01	0.28	0.36	6.90	83.70	-	-	W
	18	<0.10	27.20	0.28	0.06	1.71	46.70	60.60	<0.05	0.20	<0.01	0.23	0.34	4.92	82.20	-	-	W-PB
	19	<0.10	25.80	0.42	0.04	2.00	43.30	67.20	<0.05	0.42	<0.01	0.21	0.30	7.07	84.40	R.A.	1	PB
	23	<0.10	4.30	<0.10	0.03	0.42	12.00	28.90	<0.05	0.21	<0.01	0.26	0.48	4.67	79.80	R.A.	1	W-BL
	24	<0.10	10.00	0.38	0.04	1.42	15.20	37.30	<0.05	0.33	<0.01	0.34	0.63	4.94	80.70	-	-	W
Lake Whitefish	2	-	-	-	-	-	-	-	<0.05	0.17	<0.01	0.10	0.35	3.13	77.40	-	-	-
	3	-	-	-	-	-	-	-	<0.05	0.31	<0.01	0.09	0.32	4.12	79.70	-	-	-
	8	-	-	-	-	-	-	-	<0.05	0.12	<0.01	0.08	0.35	3.38	78.70	-	-	-
	21	-	-	-	-	-	-	-	<0.05	0.12	<0.01	0.23	0.52	3.01	79.00	-	-	-
	22	-	-	-	-	-	-	-	<0.05	0.19	<0.01	0.11	0.30	3.15	82.30	-	-	-
	25	-	-	-	-	-	-	-	<0.05	0.07	<0.01	0.06	0.62	3.12	79.00	-	-	-
	26	-	-	-	-	-	-	-	<0.05	0.26	<0.01	0.10	0.28	3.19	78.10	-	-	-
Inconnu	7	<0.10	15.30	<0.10	0.09	1.05	24.20	75.40	<0.05	0.16	<0.01	0.10	0.39	2.84	75.10	-	-	-
	2	-	-	-	-	-	-	-	<0.05	0.11	<0.01	0.10	0.42	2.66	79.80	-	-	-
Pike	1	-	-	-	-	-	-	-	<0.05	0.34	<0.01	0.26	0.25	4.17	79.40	-	-	-

[1] Parasites species: R.A. - Raphidascaris acus

[2] Liver color: W - white; W-PB - white to pale brown; PB - pale brown; DB - dark brown; W-BL - white with dark brown mass on tip

10. AQUATIC MONITORING STUDY

Agency Responsible

Department of Fisheries and Oceans, Resource Impact Section, Resource Allocation and Habitat Management Division.

Start-up Date

Winter 1983

Objectives

The objectives of the Department of Fisheries and Oceans' aquatic monitoring study were:

1. to determine the effects of the winter construction and year-round operation of the Norman Wells pipeline on fish, fish habitat, and benthos; and
2. to assess the implications of such impacts to similar northern developments.

The emphasis of the project was to document environmental change, both spatially and temporally, as a result of the project. Two major concerns were addressed:

1. The construction of pipeline stream crossings may disrupt fish migrations and destroy critical spawning, nursery, and overwintering habitats. During and after construction, subgravel water flows may be interrupted or redirected, adversely affecting overwintering habitats.

2. The use of wood chips as insulation on stream slopes may have

deleterious effects on water quality and fish habitat, and their use may:

a) cause degradation of fish habitat through the introduction of wood chips onto the stream substrate; or
b) result in decreased dissolved oxygen in the stream by increasing biological demand.

Locations

Two streams were chosen for the intensive portion of the study based on:

1. fish overwintering potential,
2. size of stream and ease of data collection,
3. access, and
4. quality and quantity of background data.

The streams under study were Hodgson Creek (Kp 305, Figure 10.1) and Whitesand Creek (Kp 271). The former received by far the most intensive study effort and provided the focus for evaluation of the effects of construction on fish and benthos. Whitesand Creek provided a site for study of the effects of wood chip slope insulation on fish habitat and water quality.

Results to Date

Stream velocity and discharge

Velocity measurements and discharge determinations were made in Hodgson Creek over the course of the study (with measuring techniques biased toward low flow conditions) in an attempt to determine any changes in stream flow rate as a result of pipeline construction or operation. Concerns were that diverted stream flow might cut off oxygenated water to fish overwintering areas downstream, or that operation of an ambient temperature pipeline in discontinuous

permafrost might cause ice-bulb formation under the stream bed, thus decreasing subsurface flow and eventually lowering downstream flow rates. Results of the study indicated that these concerns were not valid.

Stream Morphology

Basal flow in Hodgson Creek is provided by a spring source. Upstream of this point, the floodplain is confined within steep banks; downstream, banks are low and the stream channel follows an irregular path within a cobble floodplain. The floodplain itself is active laterally.

Virtually no change in channel configuration occurred within the study area from July 1984 to July 1985. However, as a result of a severe flood event in 1986, Hodgson Creek shifted to the north side of its floodplain in the vicinity of the pipeline right-of-way. This main stream channel eroded the north bank of the floodplain and resulted in flow very near to, or outside of, the area of pipe protected by deep burial and saddle weights. Many changes in channel configuration along the entire length of the study area were evident. As well, a stream cut-off channel began to form to the south of the main channel with resultant flow across and down unprotected stretches of the pipeline alignment. IPL decided to train the stream back into its former channel at the pipeline crossing. This included moving the stream channel southward to approximately mid-way between sag bends, excavating the stream channel approximately 1 m over the pipeline right-of-way, and constructing a training berm on the north bank. All of the remedial construction was undertaken in February, 1987.

Depending on weather conditions, the upstream limit of mid-winter ice cover on Hodgson Creek may vary from a point approximately 500 m

upstream of the pipeline right-of-way to the right-of-way itself. From this point downstream, flow is generally under ice. Further downstream are extensive aufeis fields, and eventually, under-ice flow is probably cut off completely. As well, a spring source adjacent to the settlement of Wrigley provides year-round flow for a short reach of stream near the mouth.

Sediment Deposition

Construction activities in Hodgson Creek led to a dramatic but short-term rise in levels of sediment deposition at proximal downstream sites. Twenty-four hour average deposition in sediment collectors placed 50 m downstream of the pipeline increased from 1 $mg.hr^{-1}$ to 140 $mg.hr^{-1}$ as a result of construction activity. Deposition rates essentially reverted to pre-construction levels by February 19, two days after construction activities ceased. Most deposited material was inorganic in nature.

Water Quality

1. Suspended Solids

Two instream construction activities affected suspended sediment (TSS) levels in Hodgson Creek during the winter of 1984/1985. These were:

1. construction of a temporary winter bridge across the stream approximately 200 m above the pipeline on December 6, 1984, and
2. pipeline trenching, laying, and back-filling on February 16 and 17, 1985.

Prior to construction, winter concentrations of total suspended

solids (TSS) at all stations were generally less than 2 $mg.L^{-1}$. Concentrations at stations unaffected by construction remained at about this level.

Winter bridge construction activities affected the TSS level, increasing the concentration to a recorded high of 26 $mg.L^{-1}$ at a location 50 m downstream of the site on December 6, 1984. Approximately seven hours after the peak, the TSS concentration at this station had decreased to approximately the pre-construction value.

Analysis of suspended sediment samples from Hodgson Creek indicated that pre-construction levels were approximately 1 $mg.L^{-1}$ and that trenching activities increased this to a recorded high of 3524 $mg.L^{-1}$ recorded 50 m downstream of the construction site. Backfilling on February 17 caused a somewhat lesser increase in suspended sediment values. High suspended sediment levels at downstream sites attenuated quickly, both over time and distance, and had reverted essentially to pre-construction values by February 21.

Values of TSS did not show a direct spatial attenuation due to the pulsed nature of sediment loading. It was not possible to follow a particular pulse of sediment-laden water as it progressed downstream; therefore, values from one station to the next were not directly comparable.

The data indicated that winter construction of the pipeline caused increased siltation of Hodgson Creek by means of direct disruption of the stream substrate, not through increased run-off from adjacent land areas. There was very little erosion of streambank material because of its frozen state and the addition of sediment to the stream essentially ceased once in-stream work

was completed. Sediment added to the water column as a result of construction activities was comprised mainly of inorganic material as evidenced by the large decrease in percent organic material in these samples.

The highest natural concentration of suspended sediments found in Hodgson Creek was 369 $mg.L^{-1}$ on June 1, 1985 at Station U2; however, this value should not be considered indicative of the very high values which occur during spring freshets. Spring freshet values probably equal or exceed those recorded during pipeline construction, although it must be kept in mind that what is tolerable in spring when natural sediment loads are normally high may be unacceptable in winter when most northern rivers are relatively clear.

2. Temperature

Pipeline construction had no discernible effect on water temperature in Hodgson Creek.

3. Dissolved oxygen

Pipeline construction had no apparent effect on dissolved oxygen levels.

4. Nutrient elements, cations, anions, and miscellaneous measurements

Pipeline construction activities appeared to have no effect on concentrations of any of the parameters measured.

5. Benthic Drift

The effect that increased sediment levels and sedimentation had on benthic drift was determined by the establishment of benthic drift stations (consisting of three drift nets at each station) both upstream and downstream of the pipeline.

Construction of the pipeline caused a significant increase in the drift of stoneflies and mayflies. Populations did not appear to recover until after the spring freshet. No detrimental effect of this loss of food supply on fish was detected, possibly because construction occurred across suboptimal overwintering habitat (i.e. the main overwintering area for fish was upstream of this location) or because loss of food organisms was confined to a relatively small area.

Fish Species

Hodgson Creek, in the vicinity of the study area, provides year-round habitat for Arctic grayling, slimy sculpin, lake chub, longnose sucker, burbot, and northern pike. While Hodgson Creek in its entirety appeared to provide good summer habitat for these species, the overwintering area seemed to be restricted to a reach transected by the IPL pipeline (overwintering may also be possible in a short open water reach near Wrigley but no fish have been observed or captured at this location). Highest concentrations of fish in winter were found in pools in open water areas of Hodgson Creek. Ice-covered areas downstream of the pipeline were found to harbour fish during winter, but sampling in these areas indicated that numbers were not high and fish did not tend to congregate there. All flow in Hodgson Creek was likely cut off by aufeis fields which began to form at Station D3 (Figure 10.2) and built up downstream. Flow was found at Station D5 in 1985 but attempts to pinpoint flow

downstream from this location were not successful. Aufeis fields downstream of Station D5 were very extensive.

To ascertain whether any downstream emigration occurred as a result of construction activities, a hoop net was maintained at approximately Station D5 (Figure 10.2) in 1985, and was believed to have effectively captured all downstream emigrants. The number of fish captured did not represent a high proportion of those occupying the area, and it was concluded that the observed downstream migration did not represent an avoidance behaviour.

Arctic grayling

Arctic grayling were the main fish species of interest in this study. Mature Arctic grayling were not well represented in winter sampling and it was likely that this group utilized the stream on a seasonal basis only, for spring spawning and summer and fall feeding, then moving downstream to the Mackenzie River prior to freeze-up. The overwintering group was comprised almost entirely of juveniles up to age four.

Stomach content analyses indicated that there were no apparent effects on feeding habits of fish as a result of pipeline construction activities.

Effects of Woodchip Insulation

Water samples were taken on a periodic basis and shipped refrigerated to Winnipeg for detailed analyses.

There was no slumping of wood chip material into the stream which could have caused an increase in oxygen demand or a deterioration of fish habitat. Water samples are being analyzed for organic acids and

no trends are evident as yet.

Conclusions

1. Pipeline sag bends were not located outside the potential channel boundaries at the Hodgson Creek crossing. As a result of rainfall in June 1986, Hodgson Creek shifted northward at the pipeline crossing to a point near the edge of, or outside, the area protected by deep burial and saddle weights. In 1986, two years after initial construction of the Hodgson Creek pipeline crossing, training works and excavation of a new stream channel became necessary at the crossing site in order to correct for stream channel shift.

2. Construction of a pipeline crossing and operation of an ambient temperature pipeline at Hodgson Creek has had no discernible effect on stream discharge or velocity. No icings were created and flow was not diverted from the natural stream channel.

3. In the twenty-four hours following completion of the Hodgson Creek pipeline crossing, sediment deposition averaged 140 $mg.hr^{-1}$ in collectors placed approximately 50 m downstream of the alignment. This compared to a pre-construction value of <1 $mg.hr^{-1}$ and an average value during construction of 42 $mg.hr^{-1}$ over a twenty-four hour period.

4. Winter bridge construction increased the suspended sediment (TSS) level from a pre-construction value of 2 $mg.L^{-1}$ to a recorded high of 26 $mg.L^{-1}$ 50 metres downstream of the crossing site. Seven hours after this peak, the TSS value at this site again approximated the pre-construction value.

5. Pipeline trenching across Hodgson Creek produced an increase in

TSS concentration from 1 $mg.L^{-1}$ prior to construction to a maximum of 3524 $mg.L^{-1}$, 50 m downstream, on February 16, 1985. High suspended sediment levels attenuated quickly both over time and distance. Other construction activities including pipe-laying and back-filling produced lesser increases in TSS than did trenching. On February 21, the TSS value 50 m downstream of the pipeline crossing was equal to the value at sites upstream of the crossing.

6. The headwaters of Hodgson Creek provided winter habitat for Arctic grayling, slimy sculpin, and a small number of lake chub, longnose sucker, burbot, and northern pike. No fall spawners utilized the headwaters of Hodgson Creek for spawning; therefore, there was no spawn in situ during winter.

7. Winter pipeline construction across the headwaters of Hodgson Creek had no direct or immediate effect on the fish which resided there during winter. Pipeline crossing activities did not lead to downstream emigration and no mortality was observed.

8. The Arctic grayling which overwintered in the headwaters of Hodgson Creek did not constitute a resident population since adults overwintered elsewhere. No Arctic grayling over age 4 were found in Hodgson Creek during winter and the youngest mature Arctic grayling found were age 5.

Future Studies

No future studies are proposed at this time.

Reports available

McKinnon, G.A., and F.N. Hnytka. 1988. The effect of winter pipeline construction on the fishes and fish habitat of Hodgson Creek, N.W.T. Can. Tech. Rep. Fish. Aquat. Sci. No. 1598. 50pp.

Young, R.J. 1986. The Effect of Winter Oil Pipeline Construction on the Benthic Macroinvertebrate Community Structure of Hodgson Creek, NWT. M.Sc Thesis. Univ. of Guelph. 67pp.

Contact

Mr. Greg McKinnon

Arctic Resource Assessment

Department of Fisheries & Oceans

501 University Crescent

Winnipeg, Manitoba R3T 2N6

(204) 949 5220

Figure 10.1 Map of the study area showing the Norman Wells pipeline alignment.

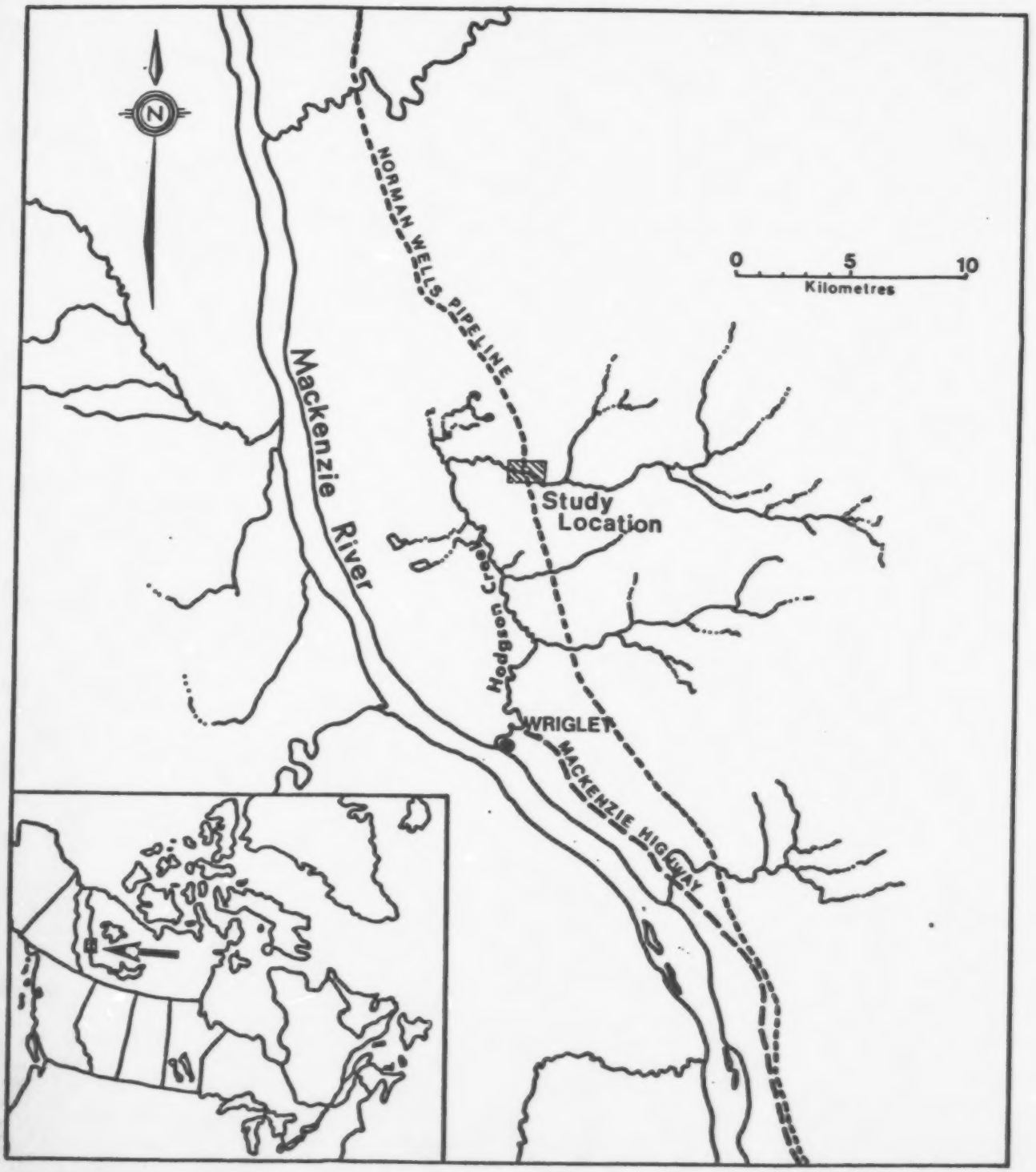


Figure 10.2 Map of the study area showing sampling locations.

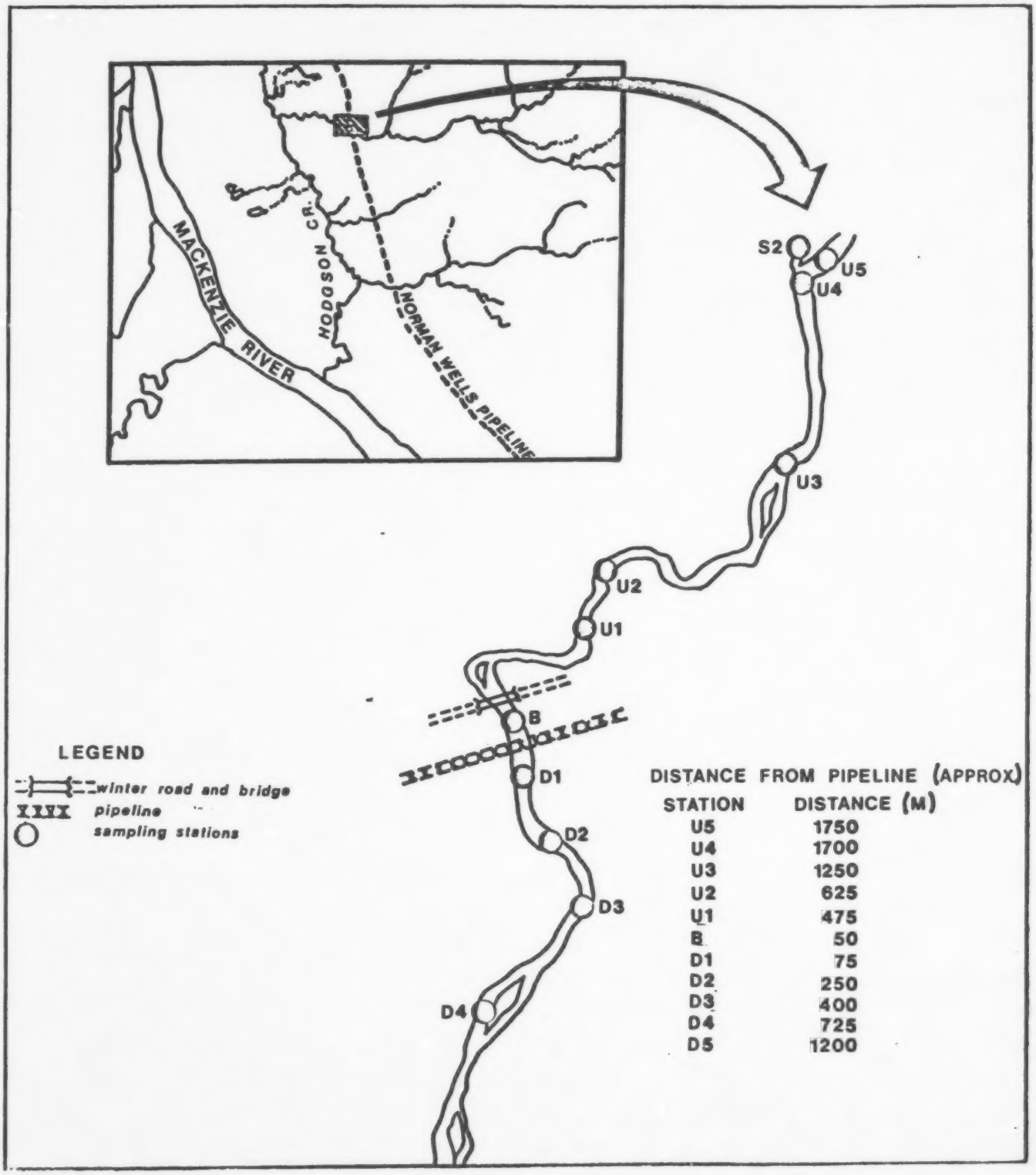


Table 10.1 Summary of sampling periods for Hodgson Creek, 1983-1986

Year 1983	1984	1985	1986
Sampling Period			
March 25-31	January 30 - February 7	January 19 - February 20	January 30 - February 1
June 4	June 24-July 7	March 19-21	May 30-June 2
July 17-26	August 24-28	May 31-July 21	August 17-19
October 11-20	October 23-25 December 6 - 7	October 19-20	

11. SNOW GOOSE HABITAT USE

Agencies Responsible

Canadian Wildlife Service, Environment Canada, in cooperation with Esso Resources Canada Limited.

Start-up Date

May 1983

Objectives

1. to determine spring waterfowl staging use of Mackenzie River islands and shorelines upstream and downstream of Norman Wells;

2. to determine the relative importance to waterfowl of habitat in the Norman Wells area compared to habitat upstream and downstream;

3. to determine the relative importance of factors influencing the use of habitat along the Mackenzie River by spring staging snow geese;

4. to assess the influence of the oilfield expansion project on spring snow goose use of Mackenzie River habitat; and

5. to identify key habitat areas important to snow geese in the spring and priority areas for protection in the event of an oil spill originating from the Norman Wells area.

Locations

See Figures 11.1 and 11.2.

Results to Date

1. In 1985, the Norman Wells area received the most use by snow geese on only one of the days surveyed; on the other three days, geese were more numerous in other reaches.

2. Use of the Norman Wells area by snow geese in 1985 was roughly equivalent to the level that occurred in 1984. However, peak use (2516 birds) of this reach was low compared to other years studied. Substantial use was made of the Windy Island area due to low water levels which caused mudflats to be exposed in 1985 (Table 11.1).

3. Based on data collected in 1972, 1980, 1981, 1983, 1984, and 1985, the following reaches were considered to be the most important for snow geese (Figure 11.3):

   a. Windy Island area;
   b. Ten Mile Island - Mac Island;
   c. Ogilvie Island - Patricia Island;
   d. Beavertail Point - Hume Island; and
   e. a section of the Fort Good Hope - Tieda River reach.

   Of these reaches, the Norman Wells area (Ten Mile Island - Mac Island reach) is probably the most heavily used on a consistent basis. The Beavertail Point - Hume Island reach ranks second in importance.

4. Mackenzie River islands and shorelines are very important for

snow geese during spring migration because virtually no other suitable habitat, free of snow and ice, exists on either side of the river. Brackett Lake is the only off-river area between Mills Lake, at the western end of Great Slave Lake, and the Mackenzie Delta, which offers attractive staging habitat conditions in the spring.

Disturbance Response of Waterfowl

1. Helicopter service flights were the chief sources of waterfowl disturbance associated with Esso's oilfield expansion project at Norman Wells in 1983 and 1984. Snow geese were the most sensitive of all waterfowl to aircraft flights. For the most part, the response of waterfowl to aircraft disturbance was minor and short term. When birds took flight, they most often returned to the same staging area within three minutes or less. This general trend was also observed in 1980 and 1981 by R. Webb, Environmental Services Ltd. In 1983, aircraft flights at altitudes between 150 and 500 m above ground level (agl) produced the highest frequency of response by waterfowl. Only 8 % of Esso's low altitude (less than 150 m) helicopter flights caused any disturbance of waterfowl.

   Almost all of the aircraft flights in 1983 followed routes which were located more than 0.5 km from staging bird flocks. Considering all aircraft types, 70 % of the flights which occurred between 0.5 and 1.0 km from staging waterfowl produced a noticeable response. At distances between 1.0 and 5.0 km, only 11% of the flights caused a response. With only one exception, waterfowl did not respond to flights which occurred more than 5.0 km away.

2. Snow goose response to helicopter flights at Norman Wells in 1985

was minor and short term in nature, according to the casual observations made that year. On the basis of the data collected in all three years of study, it was concluded that snow geese experienced only minor disturbance as a result of the oilfield expansion and associated activities at Norman Wells.

Factors Influencing Response to Disturbance

A review of literature available on the response of snow geese to aircraft disturbance indicated that the response is influenced by several factors, including:

1. aircraft type,
2. altitude in combination with distance,
3. weather (e.g. visibility, wind),
4. stage in life cycle of bird,
5. age of bird.

If specific guidelines for aircraft activities could be established on the basis of the Norman Wells studies, they would probably only apply to other developments within the same study area. Reactions to aircraft were only studied at Norman Wells. It is quite conceivable that, had the disturbance response of snow geese been studied, for example, at the well-used area upstream of Hume Island, a different pattern might have been observed. One reason for this would be that aircraft and other human activities, not related to the Norman Wells Project, had occurred at Norman Wells for many years prior to the project. In other words, if a proposal was put forward to construct six more artificial islands in the Windy Island area near Fort Norman, the response of snow geese to aircraft activity would not necessarily follow the same pattern as was observed at Norman Wells.

It is apparent, therefore, that it would be meaningless to construct very specific and binding guidelines specifying distance and

elevation restrictions for aircraft used in conjunction with all northern developments. There are, however, more general measures and guidelines which, when observed, should serve to minimize disruption of waterfowl populations. These are listed in the following section.

Recommendations

1. There is a real advantage to both the developer and regulatory agencies for open dialogue to occur early in the planning stages of a project. This allows for pre-project baseline conditions to be studied and monitoring studies to be designed cooperatively.

2. To avoid possible problems in interpretation of results due to different methodologies, consistent approaches should be followed by consultants conducting the pre-project, during-project, and post-project monitoring studies.

3. Habitat distribution information and wildlife use data are valuable components of a baseline data collection program. Having this information enables decisions to be made concerning siting of facilities, routing of aircraft, and other aspects of a development.

4. Because the responses of waterfowl to the development activities may be different from that observed at Norman Wells, close communication between the developer, the consultant, and regulatory agencies is important. This allows for more or less stringent precautions to be taken should a greater or lesser sensitivity to disturbance than expected be noted.

5. On the basis of the Norman Wells experience, it is recommended that helicopters operate at altitudes not exceeding 150 m and maintain a minimum distance of 1 km from snow goose flocks.

While a minimum distance of 0.5 km was specified in the Fourth Annual Summary Report, it is now felt that a 1 km distance is substantiated by the data collected. In addition, while it may be possible to approach snow goose flocks as close as 0.5 km without causing disturbance at Norman Wells, this may be unique to the Norman Wells area and should not necessarily be duplicated at other locations.

6. It is essential to have a monitoring program in place at the start-up time of the development where the possibility for waterfowl disturbance exists. Included in the program should be studies to determine the actual responses of snow geese and other waterfowl to disturbance. In the case of aircraft flights, the methodology used should allow the combined influence of altitude and distance on disturbance response to be measured.

7. It is important that flight controls, such as altitude, distance, exclusion areas, corridors, etc., are spelled out as much as possible in the permit or authority given by the regulatory agency concerned. It is equally important that these controls are made known to the pilots of companies providing flying services to the developer.

Reports Available

Boothroyd, P.N. 1984. Monitoring of snow goose populations on the Mackenzie River during spring migration - 1983, 1984. Canadian Wildlife Service internal report. Winnipeg, Manitoba. 4pp.

Boothroyd, P.N. 1985. Spring use of the Mackenzie River by snow geese in relation to the Norman Wells oilfield expansion project. Canadian Wildlife Service internal report. Winnipeg, Manitoba. 211pp.

Boothroyd, P.N. 1986. Influence of the Norman Wells oilfield expansion project on snow geese. Canadian Wildlife Service internal report. Winnipeg, Manitoba. 60pp.

Ealey, D.M. and J.M. Scott-Brown. 1984. A study of waterfowl disturbance at spring staging areas near Norman Wells, May 1983. Prepared for Esso Resources Canada Ltd. by McCourt Management Ltd. 77pp.

R. Webb Environmental Services Limited. 1980. Norman Wells goose survey, May 1980. Prepared for Esso Resources Canada Limited. 39pp. + appendices.

R. Webb Environmental Services Limited. 1980. Norman Wells waterfowl survey, May 1981 with observations from 1982. Prepared for Esso Resources Canada Limited. 56pp. + appendices.

R. Webb Environmental Services Limited. 1980. Norman Wells waterfowl survey, May 1984. Prepared for Esso Resources Canada Limited. 29pp. + appendices.

Sikstrom C.B. and P.N. Boothroyd. 1985. Resolving production drilling restrictions and waterfowl disturbance concerns during spring migration at Norman Wells, Northwest Territories, Canada. Proc. Conf. on Northern Hydrocarbon Development. Environmental Problem Solving, held at Banff, Alberta Sept. 24-26, 1985.

Contact

Mr. Peter Boothroyd
Canadian Wildlife Service
Department of the Environment
501 University Crescent
Winnipeg, Manitoba R3T 2N6
(204) 983-5261

Mr. Calvin Sikstrom
Esso Resources Canada Limited
237 - 4 Avenue S.W.
Calgary, Alberta T2P 0H6
(403) 237-3737

Figure 11.1 The Norman Wells oilfield study area.

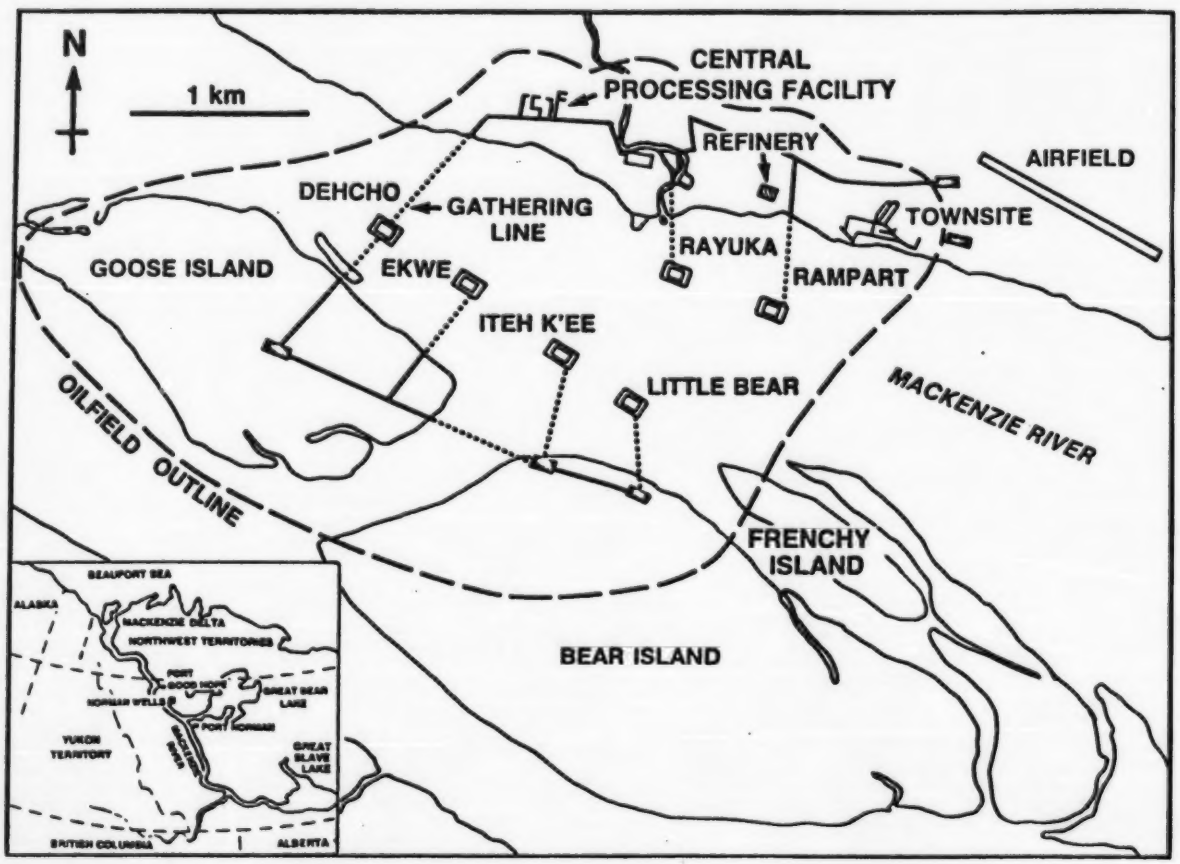


Figure 11.2 Geographic features and locations of reaches in the study area

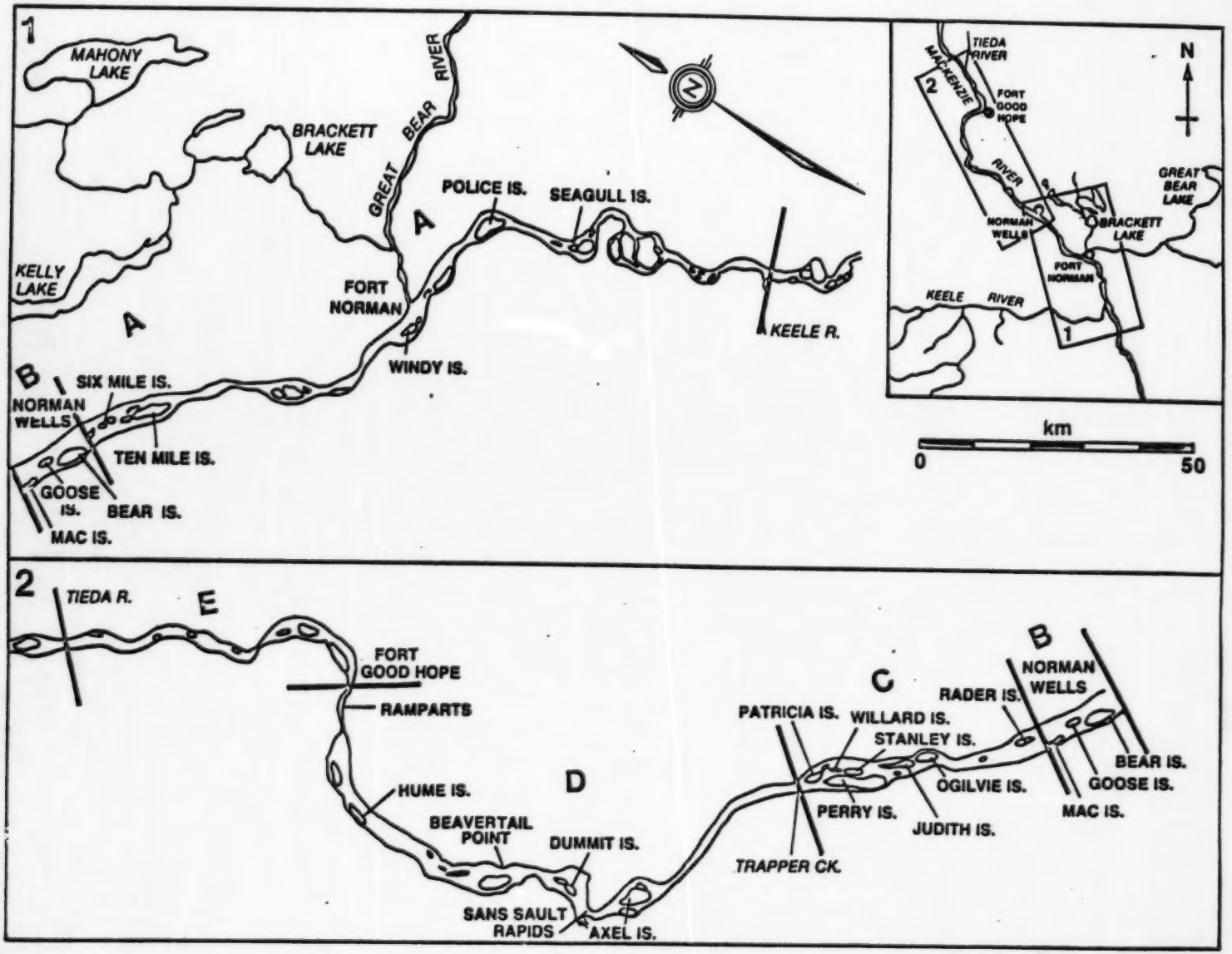


Figure 11.3 Locations of important snow goose staging areas in the study area

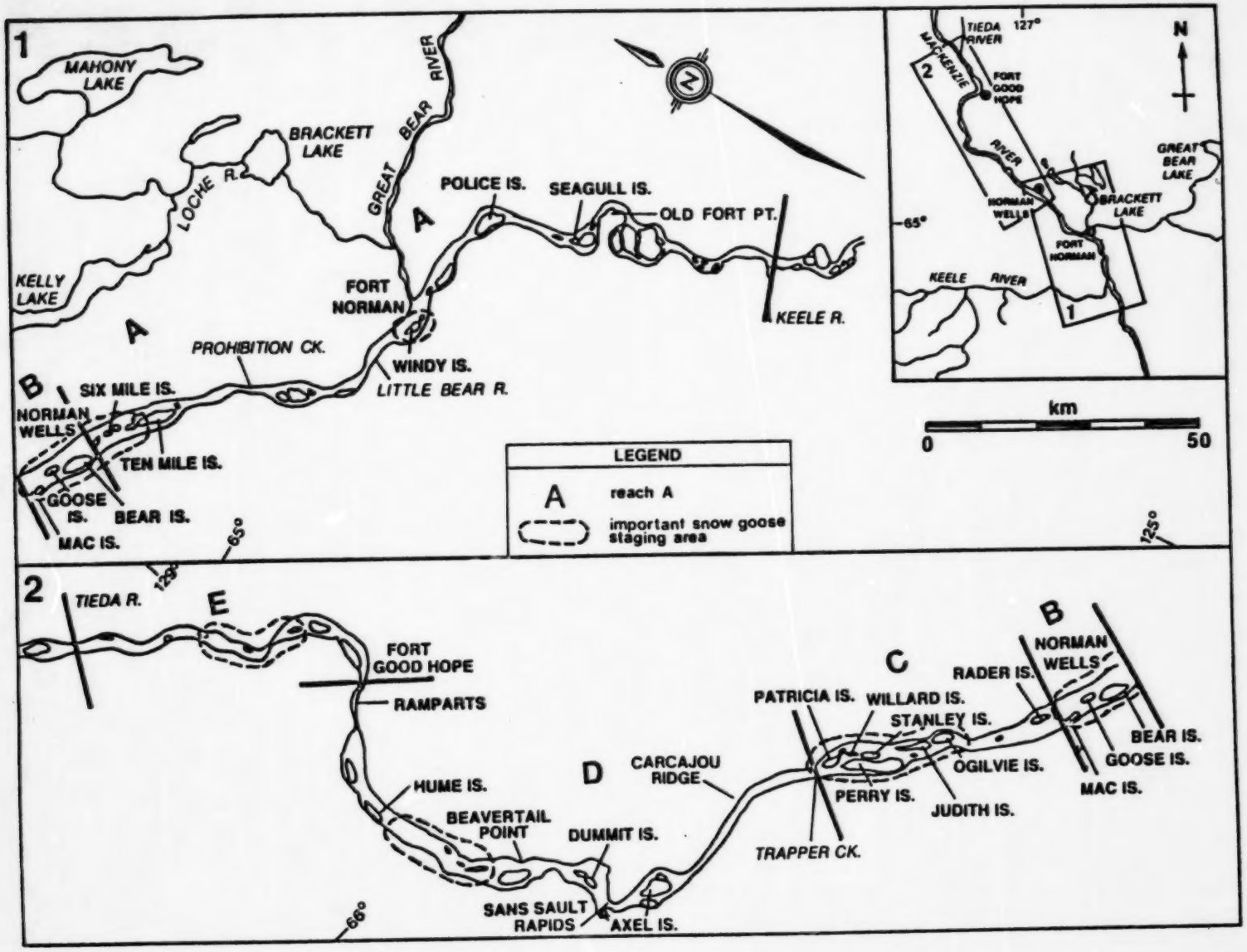


Table 11.1 Numbers and distribution of snow geese observed during aerial waterfowl surveys conducted on the Mackenzie River in May 1972, 1980, 1981, 1983, 1984 and 1985.

REACH	YEAR	2	4	6	7	8	9	10	12	13	14	15	16	17	18	19	20	23	24	25	29
A	1972[a]	.[b]	.	.	.	.	.	.	.	22 416	.	.	9 725	.	.	.	681	.	.	–[a]	–
(KEELE R. -	1980[a]	5 500[a]	5 500[a]	.	.	.	25 975	.	.	.	.	4 700	.	.	.	.	.	.	.	.	.
SIX MILE IS.)	1981[b]	20[a]	.	.	25[a]	.	–[a]	–[a]	.	–[a]	.	.	.	.	.	.	.	.	.	.	.
	1983[a]	–	.	–	.	222	.	428	–	25[a]	.	.	.	1 840[a]	12 136[a]	.	.	7 863[a]	–[a]	.	–[a]
	1984[a]	.	.	.	.	427	.	–	11	.	.	6	.	.	.	.	.	.	.	.	.
	1985[a]	.	.	.	.	.	.	1 182	.	5 902	.	1 943	.	–	.	.	.	.	.	.	.
B	1972	.	.	.	.	.	.	.	.	12 232	.	.	25 660	.	.	.	3 046	.	.	266	182
(BEAR IS. -	1980	3 700	500	7 000	.	.	.	.	.	.	4 000	5 000	.	.	.	–	.	.	.	.	.
MAC IS.)	1981	16	.	500	500	.	35	32	.	–	.	.	.	.	.	.	.	.	.	.	.
	1983	–	.	–	.	40	.	782	1 670	1 404	.	.	.	4 270	14 020	.	.	9 063	3 354	.	2
	1984	.	.	.	.	2 226	.	1 006	736	.	.	810	.	.	.	.	.	.	.	.	.
	1985	.	.	.	.	.	.	1 434	.	1 166	.	2 616	.	1	.	.	.	.	.	.	.
C	1972	.	.	.	.	.	.	.	.	1 573	.	.	5 436	.	.	.	681	.	.	25	–
(RADER IS. -	1980	.	.	.	.	.	.	.	.	.	.	4 025	.	.	.	.	.	.	.	.	.
PATRICIA IS.)	1981	400	.	750	–	.	.	–	.	5	.	.	.	.	.	.	.	.	.	.	.
	1983	–	.	–	.	90	.	45	352	807	.	.	.	1 166	716	.	.	5 361	6 567	.	–
	1984	.	.	.	.	2 266	.	2 617	1 611	.	.	736	.	.	.	.	.	.	.	.	.
	1985	.	.	.	.	.	.	250[a]	.	1 500	.	350	.	–	.	.	.	.	.	.	.
D	1972	.	.	.	.	.	.	.	.	6 323[f]	.	.	6 949[f]	.	.	.	6 230[a]	.	.	1 329	30[f]
(TRAPPER CREEK	1980	.	.	.	.	.	.	.	.	.	.	250	.	.	.	.	.	.	.	.	.
- RAMPARTS)	1981	180	.	–[a]	–[a]	.	.	–[a]	.	–[a]	.	.	.	.	.	.	.	.	.	.	.
	1983	–	.	–	.	80	.	–	16	2	.	.	.	–	20	.	.	3 425	3 462	.	8
	1984	.	.	.	.	3 264	.	6 670	2 662	.	.	666	.	.	.	.	.	.	.	.	.
	1985	.	.	.	.	.	.	.	.	2 379	.	6 183	.	2 127	.	.	.	.	.	.	.
E	1972	.	.	.	.	.	.	.	.	.	.	.	1 060	.	.	.	4 536	.	.	5 529	–
(FORT GOOD HOPE	1980	.	.	.	.	.	.	.	.	.	.	5 400	.	.	.	.	.	.	.	.	.
-TIEDA R.)	1981	–	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	1983	–	.	–	.	–	.	–	–	–	.	.	.	883	2 315	.	.	18 930	18 214	.	–
	1984	.	.	.	.	1 100	.	770	1 700	.	.	1 986	.	.	.	.	.	.	.	.	.
	1985	.	.	.	.	.	.	.	.	5 580	.	2 760	.	266	.	.	.	.	.	.	.

[a] CAMPBELL AND SHEPARD (1973)

[b] . = NOT SURVEYED

[c] – = NO SNOW GEESE OBSERVED

[d] R. WEBB ENVIRONMENTAL SERVICES LTD. (1980)

[e] TEN MILE ISLAND - SIX MILE ISLAND

[f] R. WEBB ENVIRONMENTAL SERVICES LTD. (1983)

[g] MAY 2, 5 AND 10 - CANADIAN WILDLIFE SERVICE; MAY 6, 12, 13, 17, 18, 23, 24 AND 29 - McCOURT MANAGEMENT

[h] CANADIAN WILDLIFE SERVICE

[i] RADER ISLAND - JUDITH ISLAND

[j] DUMMIT ISLAND - HUME ISLAND

[k] DUMMIT ISLAND - RAMPARTS

[l] TRAPPER CREEK - SANS SAULT RAPIDS

12. RAPTOR MONITORING PROGRAM

Agencies Responsible

Government of the Northwest Territories, Department of Renewable Resources, in cooperation with Interprovincial Pipe Line (NW) Ltd.

Start-up Date

Spring 1983

Objectives

1. to determine the effects of pipeline construction and operation on nest site occupancy and reproductive success;
2. to document the behavior of raptors nesting in the potentially sensitive zone within 3.2 km of the pipeline route; and
3. to determine if the environmental protection measures for birds of prey are effective.

Locations

Figure 12.1 shows the general location of the pipeline and control study areas.

Results to Date

1983 Observations and Results

1. Arrival and Departure

Raptor surveys were conducted by the Department of Renewable Resources in April and September to determine if the "restricted"

construction period as defined by IPL was appropriate to protect nesting birds of prey.

Ground surveys were conducted near Norman Wells, Fort Norman, and Fort Simpson during April to determine birds' arrival dates at nest sites.

First sightings:

Peregrine Falcon	April 12, 1983	Norman Wells

A departure survey on September 14 showed recent activity at Peregrine Falcon and Golden Eagle nests. Neither raptors were observed in the nesting areas at the time, but Golden Eagles could still be found in the Norman Wells area.

The "restricted" construction period was considered to be adequate to protect nesting raptors.

2. Compliance Monitoring

Only one IPL facility site was developed during the nesting season within the 3.2 km sensitive zone. Development schedules required this construction activity within the protected zone. It was conducted on a "restricted" activity basis.

3. Nest Site Occupancy and Reproductive Success

Aerial surveys were conducted in June to observe nest site occupancy. Surveys in July showed reproductive success along the pipeline route and in a control area not affected by pipeline activities. Eighteen nests were observed between Fort Simpson and Norman Wells. Each of nine "control" areas northwest of Norman Wells had at least one historic Peregrine eyrie. All active Peregrine nests produced young.

4. Disturbance Monitoring

As there were no occupied raptor nests within 3.2 km of any development site, raptor disturbance monitoring was not conducted in 1983.

1984 Observations and Results

A total of 14 areas were surveyed along the pipeline route in 1984. Of these, 13 had been previously identified by IPL (1982). These areas included two mainline construction camps and the Mackenzie River crossing at KmP 526. New construction sites for 1984 were also surveyed (Wrigley Pump Station and construction camps at KmP 226 and 285).

A survey to observe nest site occupancy in June was followed by a survey to observe production in July. These surveys were conducted along the pipeline route and in the "control" area.

1. Arrival and Departure

Information on bird arrivals in the nesting area was collected on a weekly basis from mid-March. Ground surveys were conducted near Norman Wells, Fort Norman, and Fort Simpson. Known nesting sites (1984) between Norman Wells and Wrigley were surveyed in September for the presence of raptors. A similar survey was conducted in the control areas. At that time, no raptor sightings were made.

First Sightings:

Peregrine Falcon (1 female)	April 12, 1984	Bear Rock
Peregrine Falcon (1 pair)	April 24, 1984	Norman Wells
Golden Eagle	March 26, 1984	Fort Simpson
Golden Eagle	March 29, 1984	Norman Wells
Bald Eagle	April 3, 1984	Fort Simpson

The "restricted" period (April 15 - September 15) was considered adequate in 1984.

2. Compliance Monitoring

Construction activity occurred at Camp 78, KmP 67, and at the south shore of the Mackenzie River crossing. While all of these areas were within the 3.2 km sensitive zone for nesting raptors, construction activities were not prohibited. IPL informed its contractors of special procedures to minimize disturbances.

3. Nest Site Occupancy and Reproductive Success

a. Pipeline Raptor Areas

Surveys in June focussed on nest site occupancy while July surveys recorded productivity. Thirty nine nests were recorded on each flight (34 stick nests, 5 ledge nests) of which 30 stick nests and 4 ledge nest were inactive. All nests which were active were also productive.

b. Control Raptor Areas

Twenty nine stick nests and 10 ledge nests were visited. Of these, 4 stick nests and 6 ledge nests were active and productive. Peregrine Falcon production and productivity for the pipeline areas decreased from 1983 with the loss of one productive nest.

Peregrine production for the control areas increased in 1984 to more than three times that of 1983.

4. Disturbance Monitoring

Survey results for 1984 indicated that no raptor nests were occupied within 3.2 km of any development sites or areas requiring summer maintenance work.

1985 Observations and Results

1. Arrival and Departure

Raptor survey methods did not change from the two previous years. Surveys for arrival and departure dates, and occupancy, were conducted within a day of the 1984 dates.

First sightings:		
Peregrine Falcon	April 30	Norman Wells
Golden Eagle	April 23	Norman Wells
Bald Eagle	April 3	Fort Simpson

The departure surveys conducted along the pipeline route and control areas resulted in several raptor observations in the vicinity of nest sites active that year.

Peregrine Falcon	September 13	Control Areas
Golden Eagle	September 11	Pipeline Areas
Bald Eagle	Sept. 8 - 14	Pipeline Areas
Buteo sp. (unidentified hawk)	Sept. 8 - 14	Pipeline Areas

This was the first year of the monitoring program that raptors were observed on their territories at the time of the departure surveys.

IPL's raptor protection measures were considered satisfactory in 1985.

2. Compliance Monitoring

The construction phase of the Norman Wells Pipeline was completed by March 1985. Monitoring and maintenance activities continued during the spring and summer months with no problem areas located near raptor nest sites. (Aerial overflights of the pipeline will continue on a weekly basis for the life of the pipeline. Such flights are conducted at an altitude of less than 100 m and, in some cases, pass through raptor protection zones.)

3. Nest Site Occupancy and Reproductive Success

a. Pipeline Raptor Areas

Raptor surveys conducted along the pipeline route examined the same thirteen raptor nesting areas studied in 1984. A total of 35 stick nests and 5 ledges were surveyed during the occupancy and productivity surveys, an increase of 1 stick nest from 1984.

b. Control Raptor Areas

Raptor surveys in the control area northwest of Norman Wells noted 28 stick nests and 12 ledges in the areas surveyed in 1984. Of these, one stick nest and seven ledges were active.

4. Disturbance Monitoring

Site specific disturbance monitoring was not carried out in 1985. There were no raptor areas near concentrated maintenance or monitoring work performed by IPL.

1986 Observations and Results

1. Arrival and Departure

Renewable Resource Officers in Fort Simpson and Norman Wells recorded spring arrival dates for raptors in their areas. Departure dates were not recorded as field staff were not available to do the ground surveys.

First sightings:		
Peregrine Falcon	not obtained	
Golden Eagle	27 March	Norman Wells
Bald Eagle	23 April	Fort Simpson

2. Compliance Monitoring

As part of Interprovincial Pipe Line's monitoring program, weekly helicopter overflights of the pipeline were continued in 1986. Summer maintenance of the right-of-way was not required near raptor nesting areas. The company and government scientists, working along the pipeline route, were informed of active nest sites to avoid during the nesting season.

3. Nest Site Occupancy and Reproductive Success

a. Pipeline Raptor Areas

Raptor surveys conducted along the pipeline route examined the same thirteen nesting areas studied over the past two years. Thirty-two stick nests were checked during both surveys and six were occupied, four by ravens and two by Golden Eagles. During the spring survey, four known ledge nests (scrapes) were also checked. Although none of the nests were occupied, two single and one pair of territorial

Peregrine Falcons were sighted at different locations. Four productive Peregrine nests were found during the productivity survey in July. Three of these nests were located at alternate nest sites and the fourth was found at a known site. A summary of raptor productivity and production for the pipeline area is given in Table 12.2.

b. Control Raptor Areas

Two raptor surveys were conducted in 1986. Thirty-five stick nests and eight known ledge nests were checked. Of these, five stick nests were occupied; two each by Golden Eagles and Ravens and one by Peregrine Falcons. None of the eight ledge nests were found to be occupied during the spring survey; however, single or pairs of territorial Peregrine Falcons were sighted in four areas. Productive nests were found in all four areas during the summer survey, but the number of young could only be determined at nests in two of these areas. One other nest was believed to be productive based on July ground observations of a territorial adult Peregrine near a known nest site.

Several species of non-nesting raptors were observed during the two surveys including two adult Golden Eagles and an American Kestrel. Productivity and production data in the control area is summarized in Table 12.3.

c. Comparison of Reoccupancy Rates

Reoccupancy rates for Peregrine nest sites in the pipeline and control areas are given in Table 12.1. The data indicated that both the pipeline and control areas had experienced similar high rates of reoccupancy. Although sample sizes were relatively small, there was little difference in reoccupancy rates for the pipeline and control

areas. These figures suggested that industry activities had not reduced nest occupancy along the pipeline route. Reoccupancy rates were exceptionally high in 1986, since all known Peregrine nest sites were occupied. The high reoccupancy rates may have been due to an increasing population of Peregrine Falcons in the Mackenzie Valley (Bromley and Matthews, 1986).

d. Comparison of Raptor Production

Tables 12.2 and 12.3 compare raptor productivity for the pipeline and control areas between 1983 and 1986. In 1986, Peregrine production in the pipeline areas was significantly greater than in other years. Eight young were produced from four nests and all occupied nests were productive. Three Golden Eagle young were also produced from two productive nests. The largest number of Golden Eagle young produced prior to 1986 was two in 1983 at a single nest site.

Peregrine production in the control areas for 1986 was estimated at twelve. Although six nests were productive, young could only be counted at three. Peregrine productivity (number of young per successful pair) of 2.0 was based on the total number of young observed from those three nests. A comparison of 1986 Peregrine productivity and production figures showed no significant difference for those years when the same study areas were examined. Golden Eagle production was lower in 1986 as a result of two unsuccessful nests.

4. Disturbance Monitoring

Disturbance monitoring at active nest sites was not carried out in 1986.

1987 Observations and Results

1. Arrival and Departure

Renewable Resource Officers in Norman Wells attempted to record arrival dates for raptors in the Norman Wells area. Unfortunately, Bald Eagles were the only raptors for which arrival dates were obtained: April 14, 18, and 20. A departure survey was not carried out in 1987.

2. Nest Site Occupancy and Reproductive Success

a. Pipeline Raptor Areas

The June occupancy survey examined thirty-six stick nests and five ledge nests. Raptors occupied five stick nests and two ledge nests; Ravens occupied an additional five stick nests. Peregrine Falcons occupied nests in areas C and E, and a lone adult was observed in Area D. A new Bald Eagle nest was found approximately 5 km upstream of the pipeline crossing on the north side of the Mackenzie River. Golden Eagles occupied four nest sites, with new nests found in areas B and G. A summary of nesting raptors observed is provided in Table 12.1

All nesting raptors identified in the June survey successfully raised young. Two productive Peregrine nests were found (areas A and C) during the July survey, which had not been located during the June occupancy survey. Peregrine productivity was 2.3 young per successful pair (n=3) and an estimate of Peregrine production for all areas was 9 (n=4). Golden Eagles raised six young from four nests and Bald Eagles raised two young from a single nest.

Table 12.2 provides a comparison of raptor productivity and

production over a five year period. Golden Eagles showed a noticeable increase in nest occupancy and production of young in 1987, with twice as many nests occupied and young produced compared to any other year of the monitoring program. Peregrine productivity remained similar to other years, however Peregrine production was slightly higher due to the increased number of nesting birds. The increased number of productive nests was believed to reflect a true increase rather than greater efficiency on the part of the researchers in finding occupied nests.

Observations of non-nesting raptors included three adult Bald Eagles during the occupancy survey, and five adult and two immature Bald Eagles during the productivity survey.

b. Control Raptor Areas

The occupancy survey examined 29 stick nests and 18 ledge nests. Seven stick nests and three ledge nests were occupied by raptors; Ravens occupied an additional four stick nests. Peregrine Falcons occupied ledge nests in areas GG (one eyrie) and JJ (two eyries) and unconfirmed nests were reported in areas GG and HH. Golden Eagles occupied stick nests in areas BB, EE, and KK where female birds were observed incubating. A summary of nest occupancy is contained in Table 12.3.

Peregrine Falcons were the most productive species observed (22 young estimated). A significant increase in Peregrine production for 1987 was a result of an increase in productive nests. Peregrine productivity (2.0 young per successful pair) is similar to other years. Eleven productive Peregrine nests were located during the July survey, only five of which had been observed during the earlier occupancy survey. Golden Eagles nesting in areas BB and EE each successfully raised one young. A Golden Eagle nest in area KK which

was occupied by an incubating female in June, was found to be abandoned in July. A comparison of raptor production for the control areas is summarized in Table 12.4.

Non-nesting raptors observed during the productivity survey were a pair of American Kestrels and a single Merlin.

c. Comparison of Reoccupancy Rates

Table 12.1 provides a comparison of reoccupancy rates for nesting Peregrine Falcons in the pipeline and control study areas. In 1987, Peregrines occupied at least as many nest sites as in the previous year. Where the reoccupancy rate exceeded 100% (i.e. the control areas), an increase in nest occupancy was observed. In general, reoccupancy rates for both the pipeline and control areas remained high for the five years of the monitoring program. The data indicated that pipeline activities had not reduced nest occupancy or raptor production along the pipeline route. The 1987 data suggested that the Peregrine Falcon population in the Mackenzie Valley was increasing.

Future Studies and Recommendations

1. A final year of raptor monitoring should be carried out in 1988.

2. A final report should be produced in 1988 and include:
   a. pre-construction, construction, and post-construction survey data;
   b. conclusions drawn from comparisons of the pipeline and control areas; and
   c. an evaluation of raptor protection measures and recommendations for future development projects.

Reports Available

Bromley, R.G. and S.B. Matthews. 1986. Status of Peregrine Falcons (Falco peregrinus anatum) in the Mackenzie Valley, Northwest Territories, 1969 to 1985. In press.

Matthews, S.B. 1983. Raptor Monitoring Program, Norman Wells Pipeline Project, 1983 Progress Report. Unpubl. Rept. Department of Renewable Resources, Government of the Northwest Territories, Yellowknife. 13pp.

Matthews, S.B. 1984. Raptor Monitoring Program, Norman Wells Pipeline Project, 1984 Progress Report. Unpubl. Rept. Department of Renewable Resources, Government of the Northwest Territories, Yellowknife. 9pp.

Matthews, S.B. 1985. Raptor Monitoring Program, Norman Wells Pipeline Project, 1985 Progress Report. Unpubl. Rept. Department of Renewable Resources, Government of the Northwest Territories, Yellowknife. 15 pp.

Matthews, S.B. 1986. Raptor Monitoring Program, Norman Wells Pipeline Project, 1986 Progress Report. Unpubl. Rept. Department of Renewable Resources, Government of the Northwest Territories, Yellowknife. 15 pp.

Matthews, S.B. 1987. Raptor Monitoring Program, Norman Wells Pipeline Project, 1987 Progress Report. Unpubl. Rept. Department of Renewable Resources, Government of the Northwest Territories, Yellowknife. 15 pp.

See also references provided by Interprovincial Pipe Line (NW) Ltd. in Section 1.

Contact

Mr. Steven Matthews
Department of Renewable Resources
Government of the Northwest Territories
Yellowknife, N.W.T. X1A 2L9
(403) 873-7775

Figure 12.1 General study area for the pipeline and control raptor areas.

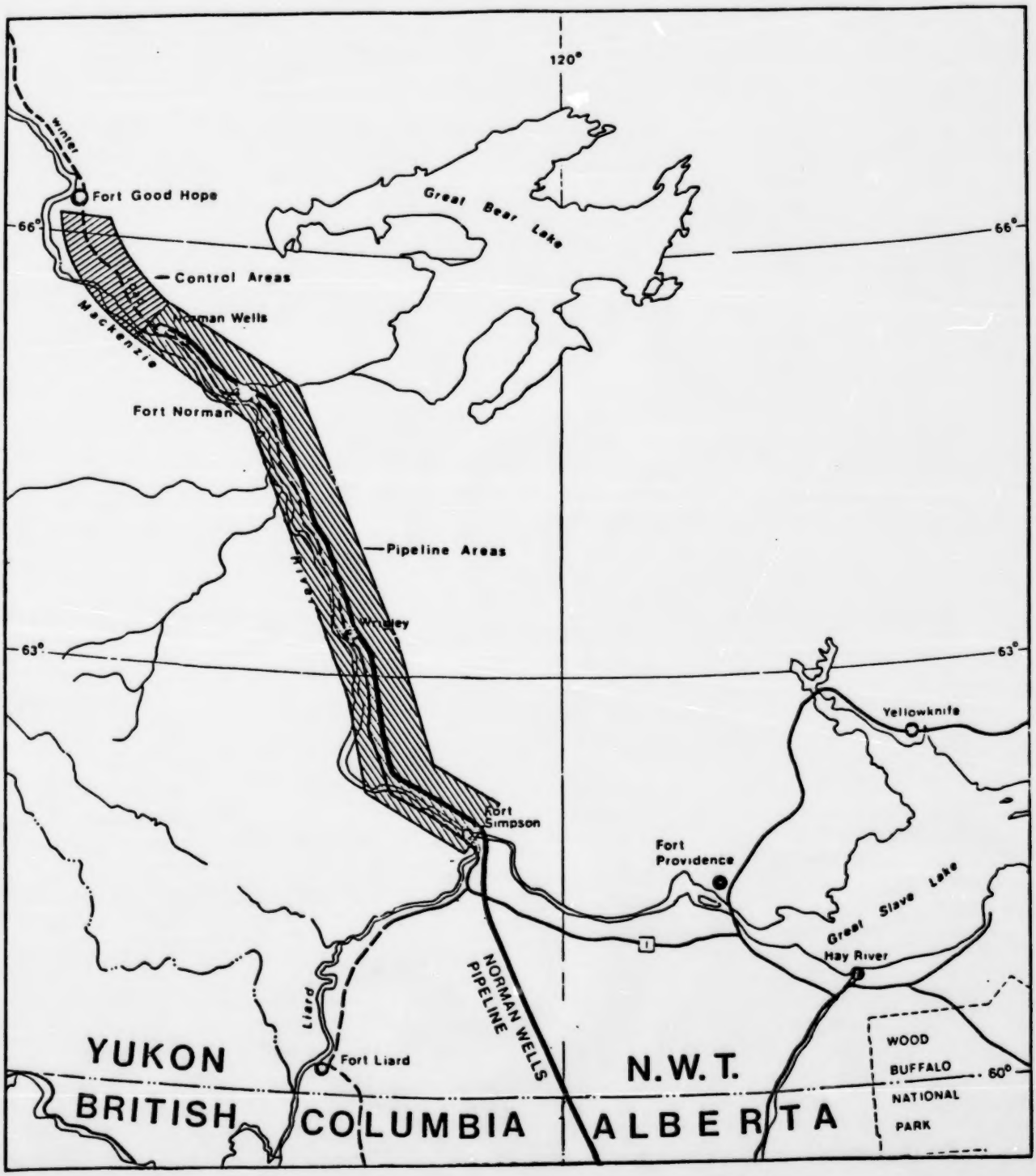


Table 12.1 Summary of Nest Occupancy in Pipeline Raptor Areas June 11, 15, 1987.

Area	Observation	
A	Great Horned Owls	1 Adult, 2 Young
B	Golden Eagles Ravens	Female Incubating 2 Young, No Adults
C	Peregrine Falcons	1 Adult, Unconfirmed Nest
D	Peregrine Falcons	1 Adult, Unconfirmed Nest
E	Peregrine Falcons Ravens	Female Incubating 2+ Young, No Adults
F	Ravens	1 Adult, 2 Young
G	Golden Eagles	Female Incubating
H	No Raptors Seen	
I	Golden Eagles	Female Incubating
J	No Raptors Seen	
K	No Raptors Seen	
L	No Raptors Seen	
M	Bald Eagles	Female Incubating

Total Number Stick Nests Observed:	36	
Total Number Occupied:	10	(Golden Eagles: 4)
		(Bald Eagles: 1)
		(Ravens: 5)
Total Number Ledge Nests Observed:	5	
Total Number Occupied:	2	(Peregrine Falcon: 1)
		(Great Horned Owl: 1)

+ indicates that the total number of eggs/young could not be determined.

Table 12.2 Comparison of raptor production in pipeline study areas 1983 to 1987

Pipeline Raptor Areas	1983	1984	1985	1986	1987
A	1 PF	1 PF	3 PF	3 PF	2 PF 1 GE 2 GHO
B	0	2 RT	0	0	2 GE
C	4 PF	0	1 GE	2 PF 1 PF 1 GE	2 PF 1 PF[1] 1 GE
D	0	0	0	0	0
E	2 RT	0	0	3 PF	3 PF
F	0	0	0	0	0
G	0	0	0	0	1 GE
H	0	0	0	0	0
I	2 GE	1 GE	0	2 GE	1 GE
J	0	0	0	0	0
K	0	0	0	0	0
L	0	0	0	0	0
M	0	0	0	0	2 BE
Estimate of Peregrine Production	5 PF (n=2)	1 PF (n=1)	3 PF (n=1)	8 PF (n=4)	9 PF (n=4)
Peregrine Productivity (No. Young/Successful Pair):	- x=2.5 (n=2)	- x=1.0 (n=1)	- x=3.0 (n=1)	- x=2.0 (n=4)	- x=2.3 (n=3)

[1] Peregrine production of 1 is given as a minimum where the number of young could not be determined.

PF - Peregrine Falcon, GE - Golden Eagle, RT - Red-tailed Hawk,
GHO - Great Horned Owl, BE - Bald Eagle

Table 12.3 Summary of Nest Occupancy in Control Raptor Areas June 12, 14, 1987.

Area	Observation	
AA	Ravens	1+ Young, 1 Adult
BB	Golden Eagles	Female Incubating
CC	No Nesting Raptors	Observed
DD	No Nesting Raptors	Observed
EE	Golden Eagles	Female Incubating
FF	No Nesting Raptors	Observed
GG	Peregrine Falcons	Female Incubating
	Peregrine Falcons	1 Adult, Unconfirmed Nest
	Ravens	1 Young, No Adults
HH	Peregrine Falcons	1 Adult, Unconfirmed Nest
	Ravens	3 Young, 2 Adults
II	No Nesting Raptors	Observed
JJ	Peregrine Falcons	2 Eggs, 2 Adults
	Peregrine Falcons	Female Incubating, Male Present
KK	Golden Eagles	Female Incubating
	Ravens	2+ Young, 1 Adult

Total Number Stick Nests Observed:	29	
Total Number Occupied:	7	(Golden Eagles: 3)
		(Ravens: 4)
Total Number Ledge Nests Observed:	18	
Total Number Occupied:	3	(Peregrine Falcons)

+ indicates that the total number of eggs/young could not be determined.

Table 12.4 Comparison of raptor production in control study areas 1983 to 1987

Control Raptor Areas	1983	1984	1985	1986	1987
AA	0	0	1 GE	3 PF	0
BB	0	0	1 PF	0	2 PF 1 GE
CC	0	0	0	0	1 PF[1]
DD	0	2 PF	0	0	0
EE	2 PF	2 PF	1 PF	1 PF[1]	2 PF 1 GE
FF	2 GE	0	0	0	0
GG	1 PF[1]	4 PF	1 PF	1 PF[1]	2 PF 1 PF
HH	0	3 PF	3 PF	2 PF	2 PF
II	2 PF	2 PF 1 GE	2 PF	1 PF[1]	1 PF[1]
JJ	-	3 PF 1 GE	3 PF	0	2 PF 1PF[1]
KK	-	3 PF	0	1 PF	3 PF 1PF[1]
Estimate of Peregrine Production	6 PF (n=3)	19 PF (n=7)	11 PF (n=6)	12 PF (n=6)	22 PF (n=11)
Peregrine Productivity (No. Young/Successful Pair):	- x=2.0 (n=2)	- x=2.7 (n=7)	- x=1.8 (n=6)	- x=2.0 (n=3)	- x=2.0 (n=7)

1 Peregrine production of 1 is given as a minimum where the number of young could not be determined.

PF - Peregrine Falcon, GE - Golden Eagle

Table 12.5 Reoccupancy rates of peregrine nest sites.

Years of Comparison	No. of Nests	% Reoccupancy
Pipeline Nest Sites		
1984/1983	2/2	100
1985/1984	2/2	100
1986/1985	4/2	200
1987/1986	4/4	100
Control Nest Sites		
1984/1983	5/3	167
1985/1984[1]	6/7	86
1986/1985	6/6	100
1987/1986	11/6	183

[1] Two new areas were added to the control areas in 1984.

13. WILDLIFE DISTURBANCE MONITORING

Agency Responsible

Government of the Northwest Territories, Department of Renewable Resources, in cooperation with Interprovincial Pipe Line (NW) Ltd.

Start-Up Date

Winter 1983/84.

Objectives

1. to determine the distribution and movements of big game and fur-bearers along sections of the pipeline right-of-way and adjacent areas before, during, and after pipeline construction,
2. to determine if pipeline construction activities influence wildlife movement,
3. to identify areas where wildlife conflicts may occur, and
4. to determine whether the environmental protection measures are effective and to make recommendations for future northern pipeline projects.

First Year Study Methods (1983/84)

Four study areas were selected along the pipeline route; one south of Norman Wells and three north of Fort Simpson (see Figure 13.1 for locations). Study areas were chosen by habitat types and defined by four straight-line transects, 1.5 km in length, running perpendicular to the pipeline right-of-way. Transects were surveyed every three weeks from January to April. Animal tracks were recorded when they

were observed to cross the transect lines. Information recorded included numbers of animal species, habitat type, and distance from the right-of-way.

Ground surveys were conducted along the right-of-way on Spreads 1 and 4 every three weeks to provide information on wildlife use of the pipeline corridor during construction.

Second Year Study Methods (1984/85)

The second year of the study concentrated on big game and furbearer movements, distribution, and use of the pipeline right-of-way and adjacent areas one year after construction. Field work was carried out in the same study areas with the same frequency as the first year.

Aerial surveys on Spreads 1 and 4 were conducted on a monthly basis from January to April to determine wildlife use of the right-of-way in the post-construction period.

Third Year Study Methods (1985/86)

During the third winter following pipeline construction, wildlife movements and distribution were monitored in the same study areas as in the previous two years. Wildlife surveys were conducted from both the ground and air. The frequency of the surveys was reduced to include an early, mid, and late winter examination of the wildlife transects.

Future Studies

No further work is planned.

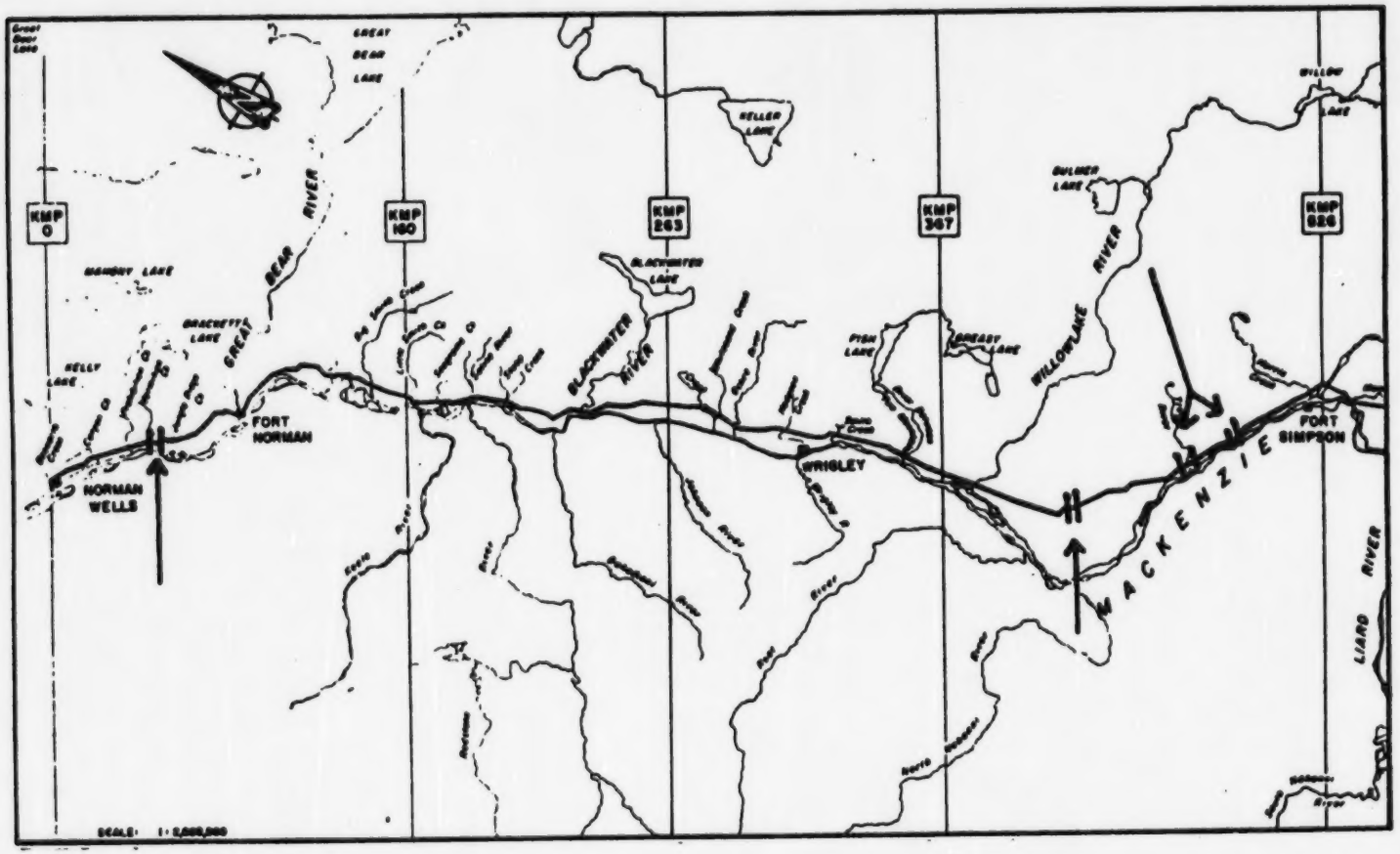
Reports Available

A final report is in preparation.

Contact

Mr. Steven Matthews
Department of Renewable Resources
Government of the Northwest Territories
Yellowknife, N.W.T. X1A 2L9
(403) 873-7775

Figure 13.1 Wildlife disturbance monitoring sites



14. RENEWABLE RESOURCE HARVEST MONITORING

Agency Responsible

Government of the Northwest Territories, Department of Renewable Resources.

Start-Up Date

Winter 1984/85.

Objectives

1. to map the important hunting and trapping areas in the Fort Simpson, Jean Marie River, Wrigley, and Trout Lake areas;
2. to monitor hunting and trapping activities of General Hunting License holders in order to determine the effects of pipeline construction on renewable resource users; and
3. to determine the effectiveness of industry measures designed to minimize impacts on hunter and trapper activities.

Methods of Monitoring Harvests

Community field workers were hired to carry out a land use mapping exercise and hunter/trapper survey for each of the four communities (Wrigley, Ft. Simpson, Jean-Marie River, and Trout Lake) being studied. General Hunting License holders who were hunting and trapping were interviewed for land use information and asked to complete a questionnaire pertaining to pipeline impacts.

Results to Date

A set of community renewable resource harvesting maps at a scale of

1:250,000 has been completed.

These maps (16 in total) have been digitized and include a base map (hydrology) and five overlays. The overlays produced are:

1. Relief,
2. Exploration, Development, and Transportation,
3. Family Trapping Areas,
4. Species Harvest, and
5. Traplines

Future Studies

No further work is planned.

Reports Available

Copies of the community renewable resource harvesting maps can be obtained from the Department of Renewable Resources. For more information, contact the project manager.

A report on the effects of pipeline construction on renewable resource harvesting is in preparation.

Contact

Mr. Steven Matthews
Department of Renewable Resources
Government of the Northwest Territories
Yellowknife, N.W.T. X1A 2L9
(403) 873-7775